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POUR L'EXPLORATION DE LA MER

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E. S. RUSSELL

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MARS 1929

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IMPRIMERIE BIANCO LUNO

The Oceanic Stage in the Life History of the Norwegian Herring.

By

Einar Lea,

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1. Introduction.

The resumption of investigations on Norwegian herring and the introduction of scale analysis in the investigations at the beginning of this century led in the course of a comparatively short time to our gaining a very much clearer conception of the biology of the Norwegian herring than had previously been possible. When we compare the contents of the works, dealing with herring, of former Norwegian investigators with the great work of our contemporary Professor JOHAN HJORT, "Fluctuations in the Great Fisheries of Northern Europe[1])", this increase in our knowledge becomes very evident. Not only did our understanding of the life history of the great race of Norwegian herring become clearer, but we were also enabled to formulate and work out problems with which we should have been entirely powerless to cope without the aid of these methods. Moreover we were enabled to discover the very violent fluctuations in the numerical strength of the year-classes which have proved to be so characteristic for the Norwegian herring. Without a thorough knowledge of these fluctuations it would be very difficult, even if at all possible, to build up any really tenable and detailed theory as to the Norwegian herring.

When HJORT published the above-mentioned work it was very far from his intention to give an account of the results obtained from a finished series of investigations. On the contrary it was his intention to arouse interest for amplifying and continuing them by showing some of the results to which the new methods led. To anyone who has not himself contributed to HJORT's work, this will be clear beyond a doubt

[1]) Rapports & Procès-Verbaux, Vol. XX, 1914.

if he reads the last chapter (VI, "Review of the present situation of the Investigations," p. 202). Before resigning his position as Director of Norwegian Fisheries, HJORT endeavoured to find ways and means to realize this plan, and to some extent he was successful, although the situation in the last 12—14 years has been extremely unfavourable for any development on a scale and in a form which would be adequate in view of the problems involved. Continuity in the most important observation work has, however, been maintained; the technique has been improved; problems have been taken up and some of them solved.

I shall here deal with the work on one of these problems and its solution. The problem was recognized as such long ago, but it soon became evident that it might remain unsolved for a long time because, amongst other reasons, a set of observations required for this purpose could only be obtained when the abundant 1904 brood had ceased to predominate in the stock, whilst for another set of observations new comparatively abundant broods were necessary whose fate might be followed up with sufficient accuracy in the statistical observation material.

This group of problems can be formulated thus: what takes place between the time when the herring is still quite in its infancy and the time when it appears, capable of reproduction, on the spawning grounds?

When it is said that the answer to this question is found, this does not imply that all possible facts relating to this transition in the herring from immaturity to maturity are known, but that knowledge has been gained as to many important points, so that this phase in the herring's life history is now known about as thoroughly as other phases, whereas formerly it was practically unknown.

This problem was to prove of great practical interest even apart from the purely scientific point of view. The connexion is as follows: The fishery for the so-called "fat herring", i.e. immature but comparatively large herring, which from 1908 to 1911 had given excellent results (between 600 and 1100 thousand hectolitres according to the statistics) afforded in the following six years a less satisfactory yield (between 250 and 420 thousand hectolitres). As this fishery for "fat herring" has always fluctuated very greatly, there would be no reason to regard this decrease in itself as anything particularly unusual but for two contributory circumstances. Firstly the fishery for "small herring" improved at the same time as the fishery for "fat herring" was of doubtful value, and secondly the employment of the purse-seine in these fisheries became more and more common, whereas previously the fishery had been carried on with shore seines or nets. Amongst many people therefore the opinion began to gain ground that all these circumstances were

interconnected. It was maintained that when so many "small herring" (prospective "fat herring") were captured, partly with the aid of the new implement, the purse-seine, this must result in a reduction in the number of "fat herring". It was further maintained that the use in itself of this implement diminished the chances of the "fat herring" fishery, partly because the influx of herring into the fiords was disturbed by the purse-seine fishery, which might commence before the herring had entered the fiord, and partly because the sea became polluted, and therefore avoided by herring, owing to all the bright scales being torn from the herring during the hauling in of the purse-seine catches.

The result of such views was an agitation and a demand for the prohibition of the use of the purse-seine and of the capture of "small herring". The State authorities decided that these demands should be subjected to a close scrutiny from various points of view and referred the purse-seine question to a committee which was to issue a proposal for a revision of the law relating to the "fat herring" fishery. The question as to the prohibition of the capture of "small herring" was referred to the Director of Fisheries on the grounds that a further study of the natural history of the herring was one of the tasks necessary for a satisfactory solution of this question.

In this manner the problem as to the details connected with the transition from the immature "fat herring" to the mature "spring herring" began to interest the administrative authorities in addition to those who were concerned with it from a purely scientific point of view. It seemed very likely that fluctuations in this group of phenomena might be a very important contributory factor in distributing the herring in the sea in such a way as to account for the yields of the separate fisheries for immature herring, i.e. the "small herring" and the "fat herring" fisheries, being as they were. There was all the more reason to attach importance to this possibility, as previous scientific observations had shown that that portion of the abundant 1904 brood, which in 1908 and 1909 were still immature "fat herring" and were present in large numbers on the usual grounds, were remarkable for their unusually slow growth. It seemed a reasonable hypothesis that this slow growth had delayed the transition of the herring to sexual maturity and caused them to remain for a longer period in the inshore waters of northern Norway where the greater part of the "fat herring" are caught.

When the problem was taken up for investigation it was decided that an attempt should be made to attack it from two sides, with the aid of observations on age and growth in conjunction with observations on the condition of the sexual organs.

First of all it was found necessary to make an attempt to single out and describe as well as possible the characteristic features of the herring which without any doubt come each year, but in greatly varying numbers, to the spawning grounds in order to propagate for the first time, i. e. young herring after passing through the transition stage to maturity (the recruit-spawners). By characteristic features are here meant age, age-distribution if any, size, growth-history, and sexual development. We can imagine such a description of these recruit-spawners being made theoretically in two ways, a more direct way by obtaining samples from what we may call pure shoals of them, shoals which have not already mingled with shoals of older spawners which in previous years have passed through the transition stage from immaturity to maturity, and a more indirect way by dividing in some manner or other samples of spawning herring, in which both recruit-spawners and older spawners are found mixed.

Both ways have been tried and it can now be stated that the direct method is the simplest and most reliable, but that it is to a very high degree dependent on favourable circumstances both during fishing and whilst material is being collected for scientific investigation. Successful attempts have several times been made to obtain such pure samples, either at the beginning of the fishery, i. e. before intermingling with the older spawners has begun, or at the end of the fishing season during the so-called "after fishery". In the following the indirect method will be described in detail. It should only be mentioned in passing that in order to lead to anything this method requires representative material which has been properly collected.

Secondly an attempt had to be made by collecting samples to gain the fullest information possible concerning the characteristic features of the immature "fat herring". This task proved to present very great difficulties, which were connected with the fact that these immature herring occur in nature in varying combinations as regards age-distribution, size-distribution etc.[1]). A large staff of trained observers would for instance be required just to collect a material which would merely afford data concerning the fishery yield. Nevertheless, the comparatively modest investigations which have been set on foot in this manner have proved necessary and useful.

By comparing and combining these two sets of observations, the one relating to the adult spawning herring and the other to the immature

[1]) Some information concerning this is published in the author's paper: "Report on Age and Growth of the Herring in Canadian Waters", Canad. Fisheries Exp. 1914—15, Ottawa 1918, p. 110.

"fat herring", it was to be hoped that conclusions would be arrived at which would play an important part in the solution of the problem under consideration.

In the following an attempt will be made to describe the results of these investigations and to indicate the consequences as regards fishery technique and the building up of a consistent theory on the Norwegian herring.

As it is not feasible to produce here the entire material on which the conclusions are based, an attempt will be made to present the description according to the following plan. Firstly as an example there will be discussed the observations for the first period, comprising two spring seasons and the intervening summer season, of which a discussion is possible. The conclusions to which this discussion give rise will be put forward, and in their presentment it will be stated what later observations of the same kind have shown, as regards the justification of these conclusions. Some investigations will then be described which were carried out in 1927, the results of which in my judgment verify the conclusions previously arrived at. Finally there will be briefly mentioned the consequences of the investigations as regards fishery technique and as regards the presentation of the natural history of the Norwegian herring.

2. Investigations during the years 1915—16.

As mentioned previously, it was an unfavourable circumstance for these investigations that the abundant 1904 brood predominated to so great an extent in the stock of adult Norwegian herring. The more individuals there are in a single brood the more difficult it will be to procure observational material for age-distribution where the relative figures for the other year-classes are sufficiently accurate; and in order to obtain greater and greater accuracy it will be necessary to increase the quantity of observations to an amount which is out of all proportion. Accuracy increases, as we know, merely as the square root of the number of observations.

Since the extent of the work was perforce confined within limits which were dictated by economic considerations and by the possibilities of procuring trained observers, the investigators had to be prepared to postpone setting about the task until conditions in nature had become favourable to them.

When the investigations on age-distribution amongst the adult Norwegian herring were reorganised in 1914 and extended, symptoms

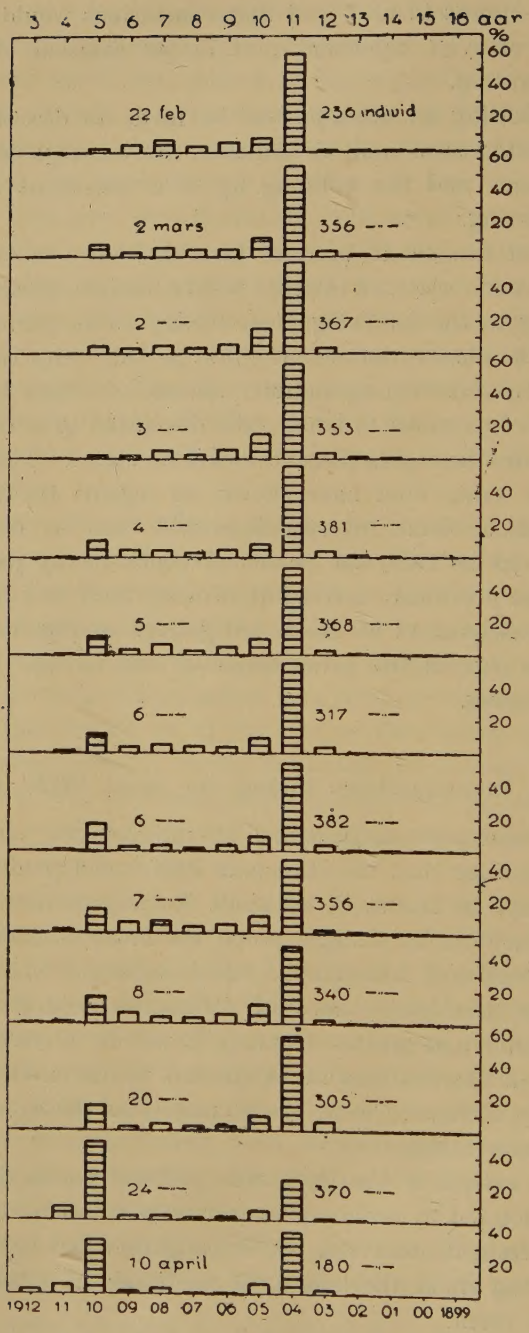

Fig. 1. Age-distribution in samples of spawning herring in 1915.

were luckily in evidence that this unfortunate circumstance would be mitigated in a short time if the observations were continued on about the same scale as in that year. It is true that the individuals of the 1904 brood still constituted more than half the stock, although they were now 10 years old, but it was certainly to be expected that the relative abundance of the brood would steadily decrease, and that natural conditions would thereby become more favourable for this investigation.

In the spring of 1915 the symptoms became considerably more pronounced, and it was even possible to gain some definite information as to the addition of recruit-spawners to the stock of spawning herring. In Fig. 1 there is given in graphic form the age-distribution in all the samples examined of herring caught with the seine during this season which were either ready to spawn or were actually spawning. All the samples caught in nets and subjected to examination are omitted, although they do not manifest any particular difference from those caught with the seine as regards age-distribution. Each horizontal section in the figure shows the age-distribution for a sample by the height of the "ladders" (where each "rung" represents 5 per cent.), and the distributions are presented in chronological order from the top downwards. The row of figures at the top of the diagram gives the age-group and the lowest row gives the year of birth (year-class).

Interesting details in the figure are as follows: 1) The first four samples show an age-distribution which is very similar to the age-distribution calculated for the previous year, when all the samples then examined are taken together and when we take into account the increase in age of one year, from 1914 till 1915. The third sample from the top especially resembles in this respect the distribution calculated for 1914 and may be here considered as an illustration of the latter. 2) In the following seven samples a change, which on the whole is progressive, appears in the age-distribution as the relative number of young, especially 5 year old, fish increases, and to such an extent that one can hardly ascribe this change to chance. These samples show great similarity with the age-distribution calculated for the same year, when all the samples are used for a basis. The sample from March 8th can in this case serve as an illustration. 3) In the two last samples there are proportionately very many of the five year old herring, and it is at the same time evident that four and three year old herring also are involved in the change, although with a considerably smaller number of fish.

The interpretation of these facts seems to be quite simple:—

1) The first four samples represent the remains in 1915 of the stock of older spawners which appeared the previous year.

2) The intermediate seven samples represent the stock during the change caused by the addition of young recruit-spawners to the congregation of older spawners already present.
3) In the last two samples these young fish are over-represented, as they appear in relative numbers which by far exceed their proportionate numerical strength when the age-distribution calculated for 1915 mentioned above is regarded as an approximately correct picture of the conditions in nature. That this is the case will be clear when the age-distribution for 1916 is discussed in the following.

If this interpretation of the data is correct, we are justified in the following preliminary assumption as to what happened in nature during the first months of 1915: the older spawners arrived first at the spawning grounds, the recruit-spawners not arriving until a later date. This hypothesis explains the peculiar features of the first 11 samples. These recruit-spawners continued to pour into the spawning grounds after a considerable portion of the older spawners had finished spawning and had disappeared from the grounds. This assumption explains why the last two samples contain, so to speak, too many of the recruit-spawners.

The assumptions may perhaps be formulated equally well by saying that the older spawners and the recruit-spawners entered the spawning ground in two contingents, which up till then had been separate, the former arriving earlier than the latter.

Finally, the two last samples indicate that at least three age-classes were present in the contingent of recruit-spawners, one of them, however, (the five year old herring) vastly predominating.

This assumption as to the two separate contingents of herring on their way to the spawning ground also explains (and is supported by) the conditions during the so-called "large herring fishery". This latter is carried on by drift-nets, takes place farther to the north and begins earlier than the fishery in the spawning area proper. All the samples investigated from this fishery show that the shoals of "large herring" are adult herring which are not yet quite ready to spawn and whose age-distribution recalls the distribution in the samples from the spawning ground which contain the group of older spawners.

In accordance with this assumption the two contingents of fish intermingle during the actual spawning season, and we should consequently be justified in expecting that also the other group, the recruit-spawners, were to be found in a similar condition (not fully ripe) during the time prior to their appearing in a condition ready for spawning.

It was to happen that all these preliminary assumptions were, if not completely verified, yet very substantially supported by the obser-

vations made during the fishery in the next season (spring, 1916). In Fig. 2 the age observations are given in a corresponding manner to those in Fig. 1, with the reservation that the individuals of the top-

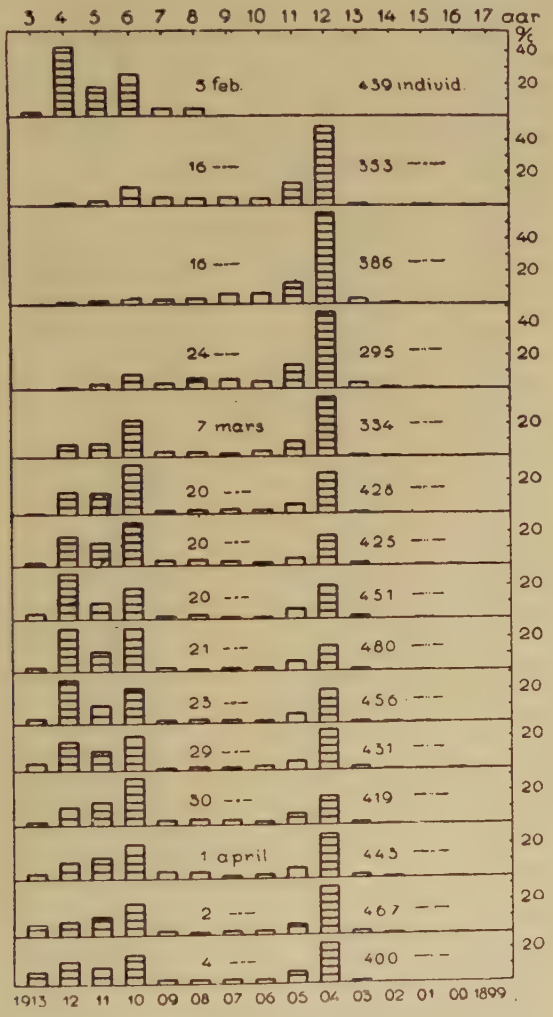

Fig. 2. Age-distribution in samples of spawning herring in 1916.

most sample were not fully ripe and were not captured in the area where the fishery for spawning herring is usually commenced, but a little to the north of it. The sample is thus to a certain extent out of place in this figure, but on the other hand it could not be placed amongst the samples of "large herring" caught at the same time. It represents some-

thing new which has hitherto not been observed and the reason for its being included in Fig. 2 is that its characteristic features explain very simply those of the real samples of spawning herring and vice versa.

For if we compare all the distributions in Fig. 2, and bear in mind what the conditions were in the previous year, we can scarcely help interpreting this first sample as representative of the group of recruit-spawners. If we disregard this first sample, the rest of the figure presents clear analogies with the figure for the previous year. There are samples from the first catches on the spawning ground proper, with an age-distribution which agrees in the main with the age-distribution calculated for the previous year. It is the older spawners which arrive first. Later in the season there occurs another change which this time is of more consequence. The younger recruit-spawners arrive later.

The last samples it is true do not present a picture corresponding to what was found in 1915. As against this fact, however, it must be pointed out that it is not to be expected that conditions will develop identically from year to year, and that the number of observations is not so great as to be looked upon as completely representing conditions in nature.

What is of importance is the fact that by suitably combining the age-distribution for the first "anomalous" sample with the age-distribution for the next samples (the older spawners), or with the age-distribution (calculated) for the previous year, or finally with single samples from the previous year, we can synthesize age-distributions, which according to wish can be given a striking resemblance with both the age-distribution for 1916 (when all the samples are taken together) and with the age-distribution for many of the later single samples from this year. As examples of such syntheses the following may be adduced. If we add six tenths of the first (anomalous) sample to four tenths of the next sample (of older spawners) we obtain a distribution which has its close counterpart in the distributions for the 8th and the 10th sample in Fig. 2. If we take four tenths of the first sample and six tenths of the next, we obtain a distribution which is very similar to the 11th sample in the figure; three tenths of the first sample and seven tenths of the next give us something which greatly resembles both the last sample in Fig. 2 and the age-distribution calculated for the season (when all the samples are taken together). If we combine the first sample in 1916 with one or other of the middle samples from the previous year (March 6th—20th) or with the age-distribution calculated for the whole of this season we obtain completely similar results.

That this must be approximately the case will be clear from a rather

closer study of the details in Figs. 1 and 2 and I shall consequently content myself here with presenting in Fig. 3 such a synthesis in graphic form, and in such a manner that the accuracy of the result can be read directly from the figure. It ought perhaps to be added that no attempt has been made to obtain the best possible numerical result. The errors in the observational material render the value of such an optimum result fictitious.

The essential point is to prove that there is an unmistakeable resem-

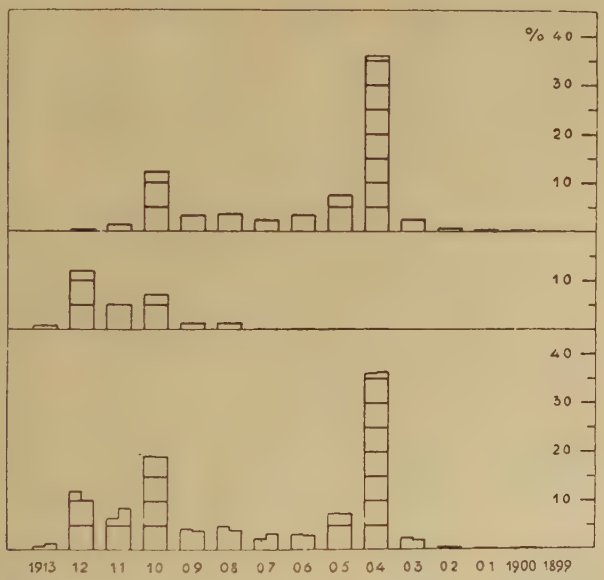

Fig. 3. Synthesis of age-distribution in the spring herring stock in 1916, combining 72.5 units of age-distribution for 1915 (above) with 27.5 units of distribution for the first (anomalous) sample in 1916 (middle figure). The result is given in the left hand column in the lowest figure. In order that the result may be tested, the distribution for 1916 arrived at by another method is given in the right hand column.

blance between the age-distributions synthesized in such a varied manner and the empirical results, whether these refer to single samples in the 1916 season or the calculated age-distribution for the whole season, when all the samples are taken together. I do not think that anyone will question the existence of this resemblance. It is, however, possible that with regard to this description of the results in 1915 and 1916 the quite justified remark will be made that they show nothing which has any validity except in so far as these two seasons are concerned. A corresponding sequence of events has, however, proved to appear time after time during the years which have elapsed between then and

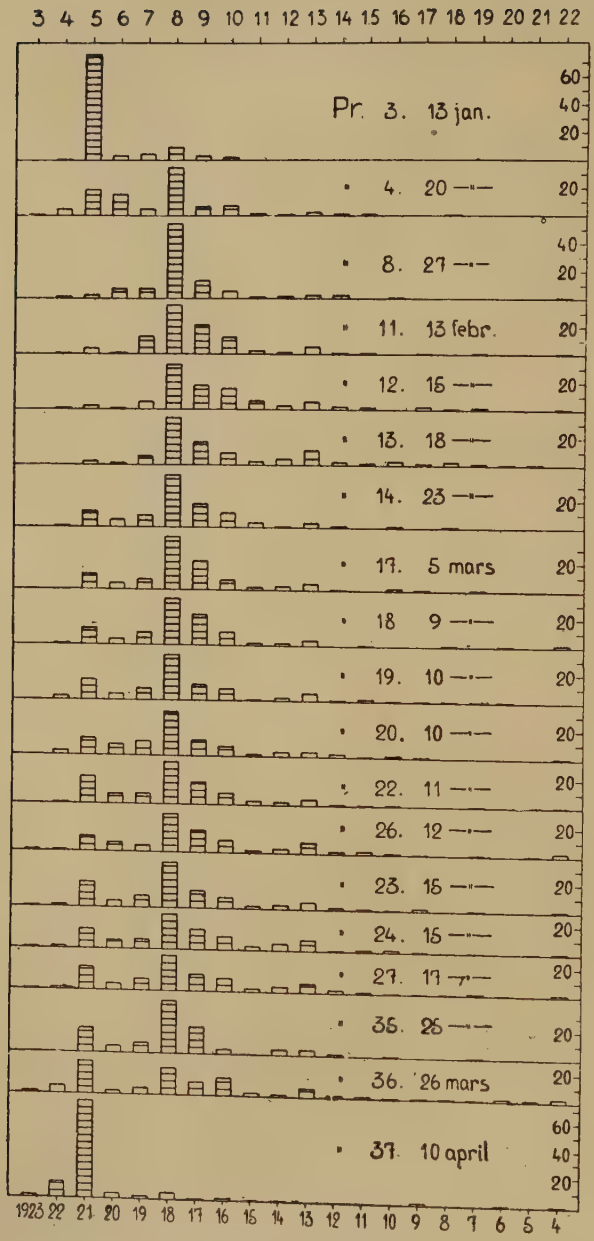

Fig. 4. Age-distribution in samples of spawning herring in 1926.

now, so that Figs. 1 and 2 may be regarded as prototypes to some extent of corresponding figures for the later years when it has been possible to state that any renewal of the stock of spawners has taken place. The best example of this is afforded by the samples from the 1926 season, whose age-distribution is given in Fig. 4. In that year a sample (probably a little impure) of recruit-spawners was obtained before the commencement of the spawning season and also a sample (similarly a little impure) at the end of the season. I regard it now as fairly certain that much the same takes place every year as in 1915, 1916, and 1926. It is another matter that the contingent of recruit-spawners can vary greatly in numbers and in some years be so small in relation to the stock of older spawners that their occurrence cannot be demonstrated in rather scanty observational material.

Regarding as verified the working hypotheses formulated above, we may proceed to pursue our problem further. It is necessary to learn what characteristic features the contingent of recruit-spawners possesses. So far as 1916 is concerned, we are in the fortunate position that direct observations are available, since the first sample in Fig. 2 may be regarded, in any case with close approximation, as a pure sample of this category. Whether the few specimens, 7 and 8 years of age, are to be regarded as an impurity or not (this being certainly the case with 4 specimens between 9 and 12 years old), is in this connexion a matter of indifference. It is certain that fish between 3 and 6 years old have come into this group, there being few of the 3 year old herring but many from the other groups.

Such direct observations are wanting for other years, but we can proceed indirectly and in several ways calculate the age-distribution, but it is more difficult to find out anything as to the size of the recruit-spawners, and the result will be less certain. The calculation of the age-distribution can be made by a subtraction, in each age-group, of the distribution found in the first samples of the season (older spawners) from the distribution as it appears in later samples, when these consist of a mixture of the two groups, or from the age-distribution calculated for the season when all the samples are taken together. Prior to this subtraction we must reduce the percentile distribution for the first samples to the extent that the differences above the category 7—8 years up to the greatest age fluctuate round about nil. Quite corresponding calculations can be made by operating with the calculated age-distributions for two consecutive years.

For 1915 we find, as mentioned previously, that the five year old herring have constituted the majority, although accompanied by some

four or three year old fish. In 1916 three age-groups were abundantly represented and in 1917 the four year old fish are found to be in a great majority, although accompanied by some five year old fish. The age-distribution amongst the recruit-spawners thus fluctuates considerably, as do also their numbers.

We can here in the sample investigation keep to direct observation by operating with the first sample in 1916 and considering it as representative of the recruit-spawners. This sample affords data relating to age-distribution and size, and the syntheses which have been made show that the contingent of recruit-spawners constituted in that year something in the neighbourhood of 30—40 per cent. in numbers of the contingent of older spawners, i.e. a very considerable renewal of the stock.

Date of this kind can then be compared with the data obtained from the material collected from the "fat herring" fishery in the summer and autumn of 1915. Upon closer investigation it proved possible to sort this material into two, apparently, natural, groups, and a third group of samples which originated partly from large fiords which to some extent had narrow inlets. The two more natural groups of samples can be characterized thus. The first group contains samples in which quite young "small herring", $1^1/_2$ years old, constitute a considerable proportion of the stock and are found in association with smaller herring, $2^1/_2$ years old. The samples in the second group contained larger herring, $2^1/_2$ years old, in association with comparatively numerous herring, $3^1/_2$ years old, a very few younger herring and solitary examples of older herring.

Even if this grouping of the samples may be regarded as more or less arbitrary, this is immaterial as regards the following line of argument. For it is clear that if we abide by this grouping (even if arbitrary) of the larger and older herring found, and contrast it with the samples from the spawning ground, we thus diminish the existing differences and make thereby an assumption which is unfavourable for the result. We shall arrive at quite the same general conclusions if we include the entire material, but the differences found then become still greater numerically. This grouping is maintained because it seems natural and correct and not arbitrary, which incidentally is confirmed by the fact that the frequency curve for length distribution becomes thereby more normal, whilst that for the entire material becomes distinctly complicated.

At the top of Fig. 5 is shown the age-distribution of the recruit-spawners (the uppermost sample in Fig. 2) and at the bottom the age-distribution in the group of larger "fat herring" from the summer and

autumn of 1915. This last distribution is obtained by the simple addition of the distributions for all the samples, since these present such great similarity that this simple method is practicable.

The two distributions show perceptible and large differences, and it is very difficult to understand how from a "fat herring" stock with an age-distribution as found there can appear by the breaking away of individuals of advanced sexual development a group of recruit-spawners with such a characteristic and varied age-distribution. The "fat herring" samples practically lack individuals of the 1911 and 1910 year-classes, which in the sample of recruit-spawners constitute not far from half the total number.

The 1912 brood constitutes the one common group of importance

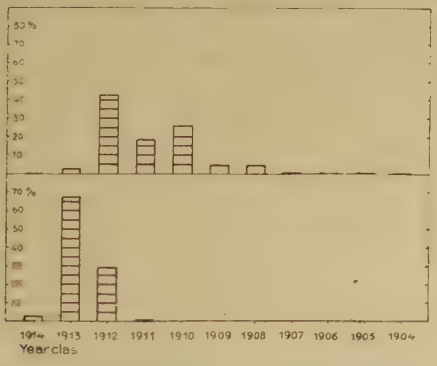

Fig. 5. Age-distribution of recruit-spawners, spring 1916, (above) and of "fat herring", autumn 1915 (below).

in the two distributions. As regards this year-class, a comparison of the age-distributions gives an indefinite result, in as much as it is likely that individuals of this year-class were "fat herring" in the autumn of 1915 and spawning herring in the spring of 1916. As regards the other two year-classes (1911 and 1910) we must on the contrary conclude that they had disappeared before the fishery for "fat herring" (and collection of samples) had commenced in the summer of 1915.

The possible assumption as to the 1912 year-class does not, however, tally very well with the conclusion drawn as to the 1911 and 1910 year-classes. A dilemma arises which nevertheless might be tolerated if other observations were decidedly in favour of the assumption. But this is not the case. There are three sets of independent observations, of which the last two in any case can scarcely be reconciled with the assumption mentioned.

For if we consider Fig. 2 and bear in mind the result of the previously mentioned syntheses, there are at least strong reasons for the presumption that the age-distribution in the group of recruit-spawners has been fairly stable i.e. that the numerical relation between the year-classes has fluctuated in approximately the same way as it would fluctuate if we arranged a comparable chance experiment. This stability indicates

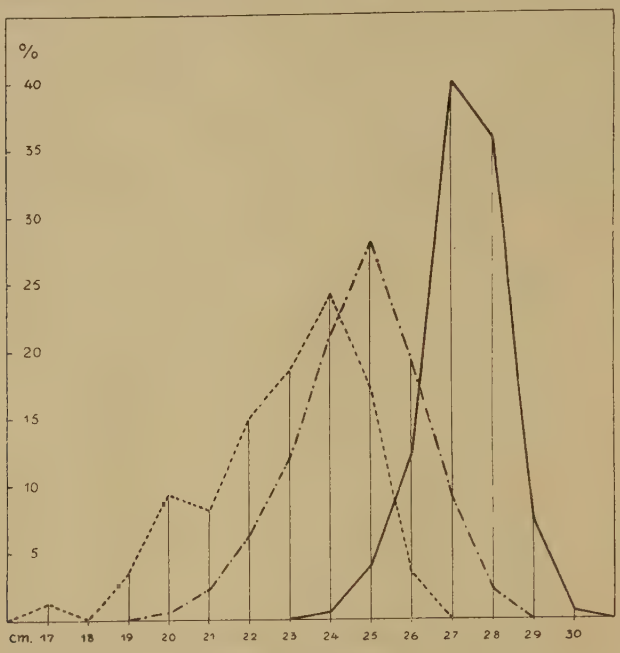

Fig. 6. Curves of length distribution of herring of the 1912 year-class:—
in samples of small "fat herring", autumn 1915, (left),
in samples of larger "fat herring", autumn 1915 (middle),
in the sample of recruit-spawners, spring 1916 (right).

quite definitely that the various year-classes amongst the recruit-spawners have been together in the sea for some time. If the 1912 year-class were so to speak derived from the stock of "fat herring", whilst the 1911 and 1910 year-classes were derived from other shoals, the age-distribution amongst the recruit-spawners could, it seems to me, scarcely be so little variable as is expressed by Fig. 2. One would expect there to be two sets of recruit-spawners and not, as it seems, only one.

We obtain the second set of observations by comparing the length of the individuals belonging to the 1912 year-class amongst the recruit-spawners and amongst the "fat herring". Fig. 6 enables us to make such

a comparison. The great difference in size is striking and unfavourable to the assumption. If the length distribution for the recruit-spawners were to be made by removing the larger individuals in the distribution for "fat herring" it would involve an assumption as to the size of the "fat herring" stock which appears improbable and in addition does not agree with later observations as to the numerical strength of the 1912 year-class, after all (surviving) individuals had become adult spawning herring.

The third set of investigations are concerned with the degree of development of the sexual organs of the "fat herring" of the 1912 year-class. These may briefly be mentioned, as showing that the sexual organs were in stages I and II (according to HJORT's scale) and had no demonstrable development in the autumn. It seems improbable that herring in stage I—II are able to develop their sexual organs to stages IV and V between October and the beginning of February, although from lack of adequate observations we cannot say that this is impossible.

Considered altogether the observations for 1915—1916 afforded good reasons for regarding as unsatisfactory the conception that there was a direct connexion, and a transition of short duration, between the "fat herring" as found in the autumn of 1915 and the spawning herring as found in the spring of 1916. It was difficult to unite the observations in a consistent theory on this basis.

It is on the other hand certain that there is a connexion, i.e. that the young immature herring along the western and northern coast of Norway become in the course of years spawning herring, which congregate along the west coast during the first months of the year. Observations from 1908—1913 afford material which forces this conception upon us, and they are not so incompatible as are the later observations with the assumption of a more direct connexion, although even in these there are points which, with the aid of information gained later, can now be seen to complicate the apparently simple picture of the connexion between the young "fat herring" and the older spawning herring which these observations seemed to give.

Observations made subsequent to 1916 have confirmed the suspicion that the assumption of a simple and close connexion between these two groups of Norwegian herring was not an accurate description of the events taking place in nature, and that it was consequently necessary to alter our views in order to bring them into logical accordance with the observations.

When the necessity for such a change of view became apparent there was no difficulty in grasping which direction it must take. The fact

that the individuals composing the shoals of young herring present along the coast are too young, too small, and too little sexually developed for the recruit-spawners to be derived directly therefrom, cannot be properly understood save by assuming that the recruit-spawners co ıe from a group of the Norwegian race of herring, which is neither usually observed nor gives rise to a coastal fishery. The conception that the herring during their development to sexual maturity pass through an oceanic intermediate stage arose as a natural consequence of the observations.

It was not difficult to verify this assumption more completely, but only indirectly, by further proofs of the sharp distinction between the immature young herring in the coastal waters and the herring ready to spawn. It is not too much to say that all the observations in our possession relating to these two groups of the same race are in agreement, and afford such indirect confirmation.

Further it was not impracticable to form indirectly some fairly definite idea as to what were the characteristic features of the herring when they were in this presumed oceanic intermediate stage. This was done by finding out what was lacking in the accessible portions of the stock (adult herring and young herring along the coast).

The difficulty, however, lay in procuring direct proof by capturing and examining the herring in the intermediate stage. No regular fishery is carried on in those areas of the sea where it was considered probable that this group of herring was to be found. Therefore direct verification was only to be obtained by fishing experiments at sea, or if, by chance, shoals of herring in the intermediate stage were to move, for some reason or other, far enough in towards the coast to come within the reach of the fishermen. It was impossible to form any definite opinion as to whether this latter alternative was likely to occur.

3. Investigations during the years 1924—27.

When Professor Johan Hjort in 1924 was setting out on his expedition to the Norwegian Sea and Greenland it was arranged that, if occasion arose, observations should be made on herring in the open sea.

For the use of my assistant in the work, Mr. Th. Rasmussen, who accompanied the expedition, I drew up a description of the characteristic features of the herring in the intermediate stage, so that if herring were captured he might be able at once to ascertain whether they were the herring we were seeking for or not. Hjort's expedition, however, afforded no material of interest in connexion with this subject, so

Mr. RASMUSSEN was unable to make use of this description. Nevertheless it proved to be of interest that the description had been made, and was in existence, before a single sample of herring from the supposed oceanic group had been subjected to examination. For when at length catches were made which might possibly have been representative of this group, it was all the more satisfactory, for the purpose of verification, that a prognosis, deduced indirectly and in fairly great detail, was already in existence. A comparison could then be instituted between what we expected, in view of our claims as to a logical connexion in the observations, and what was actually found. The description (which was accompanied by diagrams, which for the sake of brevity are here omitted) ran as follows:—

"— — we may therefore expect that the catches of young herring which are developing towards spawning for the first time will not include any great number of fish older than $5^1/_2$ years. The maximum age may be put at 6 summers and the minimum age at 3 summers.

For the rest, the age-distribution will greatly depend on whether the catches include many fish from the Vestland (many fish 3 and 4 summers old) or many fish from northern Norway (many fish 4, 5, and 6 summers old). As 4 is common to both contingents we might expect fish in their fourth year to be more numerous than the older ones, but it can easily happen that fish in their third summer will be still more numerous. Also if the contingent from northern Norway is particularly large, fish in their fifth summer may be well represented. We must be prepared for age-distributions such as that in Fig. 2[1]).

As regards the size distribution, we are juslified in expecting it to be comparatively uniformly normal, as shown in Fig. 3[1]).

The maturing herring form, according to the assumption, a group which is a selection of the population. The selection is determined by the sexual development, and this again by the growth (the size attained). The fish from the Vestland in their third summer are presumed to be about as large as the fish in their fourth summer from northern Norway etc.

The smallest length group can be put at 21 cm., the largest at 30 cm., and the medium size at 24—26 cm.

As regards the state of the sexual organs, the stages from development already begun (II) to stage IV should be represented.

The scales should present the following peculiar features. Practically all fish which are $2^1/_2$ years old, (3 summer zones), should have scales

[1]) Omitted here.

with comparatively indistinctly defined winter rings, which to some extent are difficult to see.

Fish, $3^1/_2$ years old, (4 summer zones), if we take the largest, should be similar to those of $2^1/_2$ years, possessing indistinctly defined rings, "Vestland-scales". If we take the smallest fish the rings should most often be sharp lines, as if incised with a knife, "Nordland-scales".

Most of the fish of $4^1/_2$ years and older should for the greater part have 3—4 winter rings, sharp as if incised with a knife, and amongst the oldest there should be many fish with an abnormal growth in some way or other, e.g. the second year's growth smaller than the third year's, the third year's smaller than the fourth year's, etc. (Fig. 4)[1]). It is assumed that the scales are taken from the area shown in Fig. 5[1]). The outer rings (4th and 5th) can be less distinctly defined than the inner (formed whilst the fish were in the X-group[2]) area.

Should fish older than 6 years be found in the samples, it is possible that they may be fish of about the same size belonging to other populations (Shetland), interspersed in the group. These will be distinguished by their rings being less sharply defined and by their summer growth after the third summer being very slight (see Fig. 4)[1]).

Up to now it has been assumed that all the fish which are developing towards spawning for the first time are mixed together. They can, however, be looked upon as divided into two groups, of which the one comprises the fish which have not developed so far as to take part in the spawning the coming spring, whilst the other group comprises the fish which are so far developed sexually as to spawn in the spring. It may be assumed that these latter sooner or later leave the less developed fish and set out on their spawning migration. If this has occurred there will thus be two groups, the one comprising smaller fish in stages II—III, and the other comprising larger fish in stage III and possibly III—IV.

The group of more developed fish will then presumably lack fish in their fourth summer with sharply defined rings (Nordland herring) and fish in their third summer with vaguely defined rings (Vestland herring), both of which must be assumed to be present and to constitute the bulk of the group of less developed fish."

The main points in the description are the following: age from 3 to 6 summers (so many summer zones on the scales), age-distribution greatly dependent on circumstances, with the $3^1/_2$ years' group as the central one, size between 21 and 30 cm. with the average length of 24—26 cm., sexual development from II to IV, possibly an admixture

[1]) Omitted here.

[2]) See below page 27.

Fig. 7. Scales from a herring nearly two years old, caught in autumn 1928 in the waters of northern Norway.

of herring which do not belong to the Norwegian race, and finally certain peculiarities as to the scales of the herring which it will be necessary to describe a little more closely.

Experience has shown that there are differences in the appearance of the winter rings on the scales from young herring which are caught

Fig. 8. Scales from a herring nearly two years old, caught in autumn 1928 off the southern part of the west coast of Norway.

in various waters along the Norwegian coast. The scales on the herring from northern Norway have rings which as a rule are sharply defined, whilst herring from the southern part of the west coast have scales with more vaguely defined rings. It is not easy to explain the differences in words; they must be seen to be realised, but they undoubtedly exist. Figs. 7 and 8 give some idea of how they appear to the investigator who carries out the scale analysis. The photographs show two scales, one from a young herring captured in the northern waters and one from a herring from the southern waters of Norway. The examples are selected so as to compensate for what is lost in the processes of photography and reproduction, and in order to illustrate the nature of the differences.

In recent years we have sought to make use of these characteristic features in the scales in analyses of the material collected in Norway, and at present it looks as if this type of analysis is at least a valuable supplementary form of observation, when it is a question of distinguishing Norwegian from other herring or of distinguishing between the various groups which together make up the Norwegian race of herring.

The first samples of herring, which could be supposed to represent the oceanic stage in the development of the herring, were derived from catches made along the west coast of Norway in May—June 1924, when a small but irregular fishery developed in that area in the neighbourhood of Kristiansund. Unfortunately it was not realised what value these samples might have had for this investigation, for which reason they were not examined as closely as they deserved. The data we possess for these samples (age, length, scale-type) indicate, however, that here were representatives of the group we were in search of.

The summer of 1925 gave better results. In that season we obtained a catch, also from the west coast, and in addition a number of drift net catches were made in the open sea during the Swedish and Norwegian fishing experiments in the entrance of the Skagerak, and these catches possessed features which are of great interest in this connexion. But these samples also were examined before their significance could be appreciated, so that the chance of a specially close examination was wasted. This set of samples, and a number of samples from 1926, together with one sample from the spring of 1927, have, however, proved to be of very great interest, and they will accordingly be discussed later.

In the summer of 1927 an occasion arose to make more complete observations. Along the coast in the neighbourhood of Bergen various herring appeared which the fishermen had difficulty in classifying amongst their "sorts" of herring. For the time and place the herring were large, and the condition of the sexual organs varied greatly from herring to

herring. According to the fishermen's statements, there were many of them off the coast but they were unwilling to enter the sounds and the fiords where they could be captured with shore seines. Many catches, although small ones, were made in the course of two or three months, and as from the very commencement it was plain that the herring probably belonged to the oceanic group we were in search of, an adequate number of herring were collected in small lots. These herring were successively examined as to the essential characteristic features, including the number of vertebrae, chiefly in view of a possible admixture of "extraneous" herring.

From the analysis of the material thus collected, it appeared that the separate small samples were greatly at variance, in as much as the number of herring with three summer zones on the scales varied greatly from sample to sample. One could not help getting the impression that in the waters where the catches were made there were two groups of herring which were in process of uniting into one group. As a consequence of this variation, we cannot expect to determine from these samples what the age-distribution is or has become after the mixing process came to an end. For the rest, there was so much agreement between the samples that it was regarded as permissible to lump them together when the observations were being worked up. That this was justified will be seen from the regularity which characterizes the frequency columns which appear upon the material being analysed.

The most important features in the material considered as a whole will be clear from Table 1, in which the length and age of the fish are the two main divisions, but where there are also made other distinctions, which require explanation.

A distinction is made between individuals, whose age entitles them to a position in the oceanic group, and young herring, $1^1/_2$ years old, which are possibly only an admixture. Herring of this age are always to be found in summer in the waters from which the samples are taken.

A distinction is further made between herring, whose scales on the above mentioned analysis of the features of the winter rings seemed to indicate that they belonged to the Norwegian race, and herring whose scales seemed to indicate that they were not Norwegian herring. This distinction has, as will be shown later, given interesting results, both as regards methods and from a biological point of view.

Finally, each age-group in the assumed oceanic group is divided into two, according to the appearance of the winter rings on the scales. Herring whose scales had more sharply defined rings are allotted to the sub-group "northern", and herring whose scales had less sharply defined

rings to the sub-group "southern". These terms must not be understood in a too literally geographical sense. For the "northern" type probably begins, according to other investigations, at Trøndelagen, i.e. along the southern half of the Norwegian coast. The classification is made in accordance with the scale-type, independently of geographical considerations, whilst the terms "northern" and "southern" have been chosen because, taken on the whole, they are characteristic. The distinction may in fact be taken as provisional.

The group of Norwegian herring which has hitherto been characterized by the term "oceanic intermediate stage" was called, as long as its existence was hypothetical, the X-group, and this term is retained for the sake of brevity.

From the numbers in the columns farthest to the right in the table, it may be seen how the result of the analysis is affected by the exclusion of the youngest and the "extraneous" herring. Further, in the last column is given the frequency series for length distribution which is alluded to in the prognosis which was worked out beforehand in 1924.

If we now consider the bottom horizontal rows showing the age-distribution, we shall see that individuals, $2^1/_2$—$6^1/_2$ years of age, occur amongst those herring which have not been excluded, as constituting an admixture, either because they are too young, or because their scales seem to indicate that they belonged to races other than the Norwegian. The agreement as to this point between the prognosis and what was actually found is quite good, as the number of individuals which are outside the range of the prognosis (4 herring, $6^1/_2$ years old and 14 herring, $1^1/_2$ years old) constitute only 3 per cent. of the total.

Similarly the fact that the bulk of the individuals are from $2^1/_2$—$4^1/_2$ years old is in close conformity with the prognosis. On the other hand it may possibly be regarded as a slight error in the prognosis that the age-group, $3^1/_2$ years, was especially pointed out as the central and typical one. It proves here to be numerically weaker than both the $2^1/_2$ and the $4^1/_2$ group. This disagreement is, however, more apparent than actual, since from other observations it seems probable that the 1924 year-class is bad compared with the 1923 and 1925 year-classes, and that the prognosis is correct for the ideal case, i.e. when there are no such fluctuations in the year-classes.

The herring, $2^1/_2$ years old, belonging to the 1925 year-class, are in the majority in the material, but this fact, as mentioned previously, has no definite significance, since the number fluctuated so greatly from sample to sample. It is, however, highly probable that this 1925 year-class will prove to be very abundant. A portion of this year-class

Table 1. Analysis of the material from the autumn of 1927.

Length cm	Norwegian Herring of the X-group															Admixt.		Total		Percent		
	$2^1/_2$ year			$3^1/_2$ year			$4^1/_2$ year			$5^1/_2$ year			$6^1/_2$ year			$1^1/_2$	3—12					
	Southern	Northern	All	Southern	Northern	All	Southern	Northern	All	Southern	Northern	All	Southern	Northern	All	Small Norweg.	Extran.	X-group	All	X-group	All	Prognosticated
18.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	..	..	4	..	0.6	..
19.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	4	..	..	4	..	0.6	..
20.....	2	1	3	..	..	..	..	..	..	..	..	..	..	..	..	1	..	3	4	0.5	0.6	..
21.....	7	1	8	..	1	1	..	..	..	..	..	..	..	..	..	3	..	9	12	1.5	1.8	2.5
22.....	26	16	45	1	..	3	..	..	..	..	..	..	..	..	..	2	..	48	50	7.8	7.4	9.5
23.....	87	25	115	5	6	11	..	3	3	..	..	1	..	..	..	..	4	130	134	21.0	19.7	14.7
24.....	76	18	99	5	11	18	..	4	4	..	..	1	..	..	..	..	6	122	128	19.7	18.9	18.4
25.....	39	4	45	12	12	25	1	31	32	..	2	4	..	..	..	..	12	106	118	17.2	17.4	19.6
26.....	3	1	5	12	9	25	4	63	70	..	8	8	..	..	..	..	11	108	119	17.5	17.5	15.9
27.....	..	..	..	4	1	5	8	23	34	..	26	27	..	..	1	..	8	67	75	10.8	11.0	9.6
28.....	..	..	..	1	1	2	4	2	6	..	11	11	..	..	1	..	4	20	24	3.2	3.5	5.4
29.....	..	..	..	1	..	1	..	1	1	..	..	..	..	..	..	..	2	2	4	0.3	0.6	2.5
30.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	..	..	2	2	0.3	0.3	1.4
31.....	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0.5
32.....	..	..	..	1	..	1	..	..	..	..	..	..	..	..	..	..	..	1	1	0.2	0.1	..
Total....	240	66	320	42	41	92	17	127	150	..	47	52	..	..	4	14	47	618	679	..	..	..
% of all..	..	..	47.1	..	..	13.5	..	..	22.1	..	..	7.7	..	..	0.6	2.1	6.9	..	..	..	..	..
% X-gr...	..	..	51.8	..	..	14.9	..	..	24.3	..	..	8.4	..	..	0.6	..	..	..	..	..	..	..
																			Mean length...	24.6	24.6	24.9

formed the basis last autumn for a fishery in the north of Norway which was unique in its abundant yield.

If we consider the classification into "southern" and "northern" types of the various age-groups, it will be seen that the "southern" type is in majority in the youngest group, there being an equal quantity of each type in the next group, whilst in the older groups the "northern" type predominates, which conforms fairly closely with what had been expected. The fish of the "southern" type tend to be slightly larger than "northern" herring of the same age. It had been expected that this difference would be more pronounced.

As regards the individuals whose scales were not of the Norwegian type, 47 were found between 3 and 12 years of age, and between 23 and 29 cm. in length. That the possibility of such an admixture had been reckoned with was due to a conjecture that the haunts of the oceanic group of young herring did not lie so far from the northern North Sea that an occurrence of mixed shoals was unlikely. Experience has shown that this hypothesis was correct. There can be no doubt whatever that at any rate the majority of the 47 individuals, which are entered as "extraneous", do not belong to the Norwegian race, but probably to one of the North Sea races. The proof of this was furnished by the counting of the vertebrae, which was a part of the investigation. The latter was carried out in the following manner. All the observation work on the actual herrings was done by my assistant Mr. RASMUSSEN who kept his own records. The scale preparations, furnished merely with serial numbers, were examined by me, each in turn as it reached me. The numbered herring were preserved and the vertebrae counted. after I had made my notes on the type ("southern" or "northern" Norwegian, or "extraneous") in a separate record. Not until these independent observations were finished were all the data brought together and analysed. The results will be described in detail on some other occasion. It will suffice here to give the most summary comparison. The mean number of vertebrae (Vert. S., HEINCKE) for the 47 "extraneous" herring was 56.6 and for the remaining herring 57.1. The standard error of the 0.5 difference was 0.1. The mean vertebral number of young fish caught during the same summer amongst the islands forming a belt along the coast ("Skjærgaard") was 57.1 (fish $1^1/_2$ years of age) and 57.0 (fish aged 6 months). This difference is so large in proportion to its standard error that it must be genuine.

The figures in the columns farthest to the right afford a comparison between the length distribution as found (in two alternative categories for the X-group alone and for the total number of fish) and that anti-

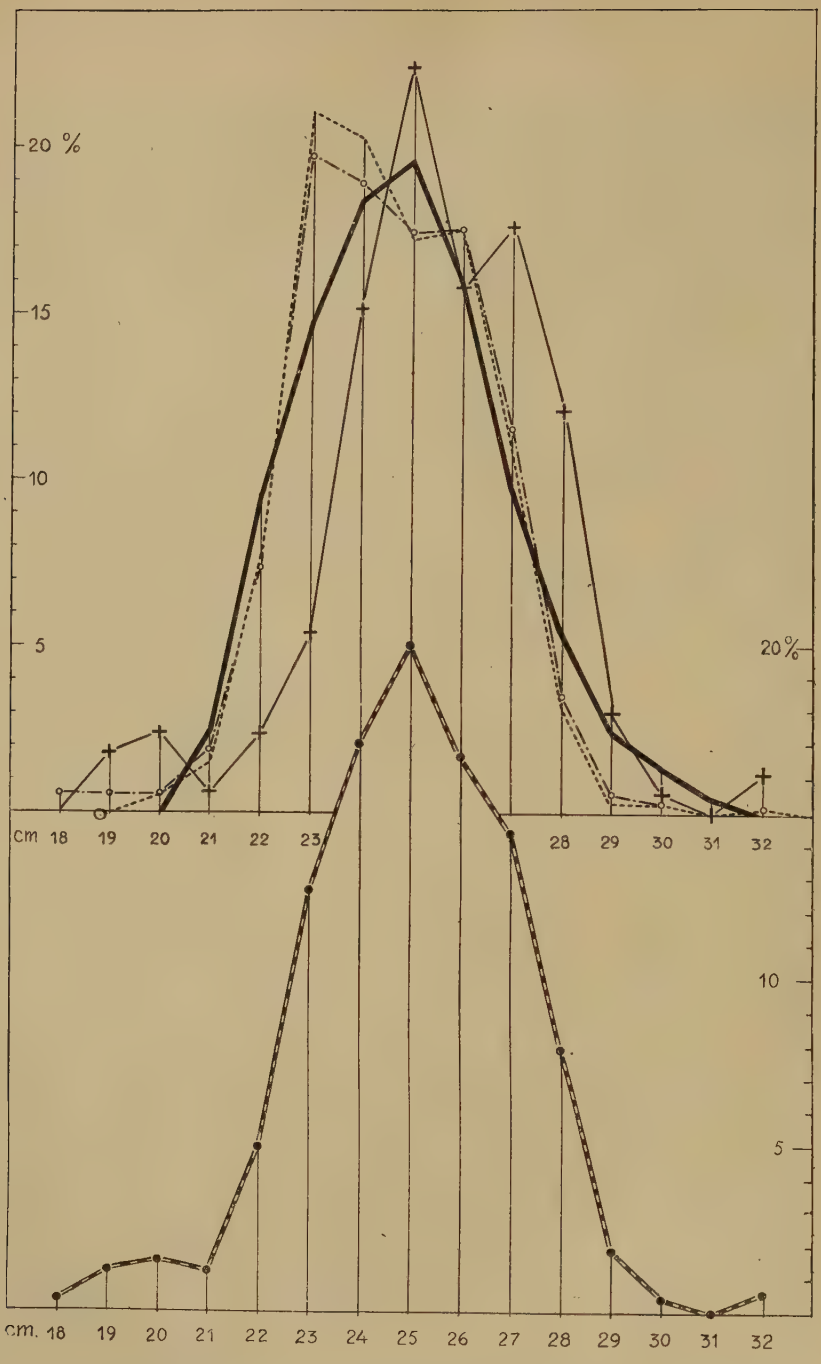

Fig. 9. Curves of length distribution for the oceanic young herring in samples from spring and autumn 1927, compared with the curve given previously.

Upper section: thin line with crosses — sample from spring 1927, dots — samples from autumn 1927, the youngest and the "extraneous" herring being excluded, dot, line, and circle — the same samples but all fish included, thick line — the curve given previously.

Lower section: the samples from spring and autumn combined, with equal parts of each.

cipated in the prognosis. The series of figures are of course not identical, but bear as strong a resembance to each other as one may reasonably expect when one takes into account the fact that the distributions cannot be expected to be completely constant.

At the top of Fig. 9 the length frequency curve as plotted beforehand is given, together with the frequency curve in accordance with the two alternatives for Table 1. Further there is included the corresponding curve for a sample of herring which originates from a catch in the spring of 1927, and which in all probability is also a representative of the oceanic group, but from an earlier date and before the young herring of the 1925 year-class (and possibly also a number of individuals belonging to older groups) had intermingled with them.

This sample also, the characteristic features of which are shown in Table 2, contained a number of "extraneous" herring, but we have no verification from vertebral counts in this sample.

Table 2. Analysis of sample nr. 31. Kalvaag, 26th March 1927.

Length in cm	Norwegian Herring of the X-group					Extianeous	Total		Percent	
	1925 2 year-group	1924 3 year-group	1923 4 year-group	1922 5 year-group	Older Norwegian		Norwegian alone	All	Norwegian alone	All
19.....	2	..	..	..	..	..	2	2	1.5	1.3
20.....	1	2	..	..	..	1	3	4	2.3	2.5
21.....	1	..	..	..	..	..	1	1	0.8	0.6
22.....	..	1	3	..	..	..	4	4	3.0	2.5
23.....	..	3	6	..	..	..	9	9	6.8	5.6
24.....	..	7	9	3	..	..	19	19	14.3	11.9
25.....	..	10	11	15	..	5	36	41	27.1	25.6
26.....	..	3	12	7	..	2	22	24	16.5	15.0
27.....	..	..	9	7	2	10	18	28	13.5	17.5
28.....	..	..	6	6	1	7	13	20	9.8	12.5
29.....	..	..	1	3	..	1	4	5	3.0	3.1
30.....	..	..	..	..	..	1	..	1	..	0.6
31.....	..	..	..	..	..	..	..	..	..	..
32.....	..	..	..	..	2	..	2	2	1.5	1.3
	4	28	57	41	5	27	133	160	100.1	100.0
							Mean length...		25.4	26.1

As will be noticed, the herring in this sample were a little larger than those in the autumn samples, but in this sample also the resemblance with the frequency curve plotted beforehand is satisfactory.

If we consider this sample and those from the autumn as two variants within the same main group, and if we add together the two percentile frequency distributions, a distribution is obtained which is given at the bottom of Fig. 9. It is, as will be seen, fairly similar to the curve plotted beforehand.

The observations as to the state of the sexual organs of the herring examined showed that in this point there was a marked divergence from what had been expected; i.e. this divergence is not in accord with the hypothesis that the catches investigated are representative of the entire oceanic group. There were in fact only a few individuals in which the sexual products were in an advanced state of development, far fewer than one would expect if there were many herring in the catches which were to spawn in the coming spring (1928). Moreover there were many, especially of the younger individuals, which were in stage I (HJORT's scale), or were a little beyond this infantile stage.

These observations indicate quite definitely that the oceanic group of herring in the summer of 1927 was already split up into two subgroups, the one comprising individuals with advanced sexual development (prospective spawners in the spring of 1928), whilst the other group, which is represented by our samples, contained individuals which would not be ready to spawn in the spring of 1928. Such a separation must take place once a year, and according to these observations it seems to have occurred quite early in the year.

This assumption would be supported if the herring, which actually came in as spawners for the first time in the spring of 1928, proved to be considerably larger than the herring of the same age in the samples subjected to examination. This will be shown to be the case when the detailed analysis of the observations for the spring of 1928 has been made. According to a preliminary calculation which gives approximate values, the average lengths for the year-classes 1924, 1923, and 1922 were 27.5, 28.8, and 29.6 cm. respectively, i.e. considerably more than the corresponding figures for the material from the summer of 1927.

Altogether these comparisons show so great a resemblance between what was expected and what was actually found that in my opinion we are bound to draw the conclusion that the shoals of herring, from which the observational material has been obtained, have had those very features which were to be expected if the premisses and assumptions as to the oceanic stage were correct. The existence of this phase in the life history of the herring is regarded then as proved, even though it was not possible at the same time to indicate the haunts of this group in the open sea, and although these oceanic young herring were found close in to the coast, in fact right in the fiords and sounds.

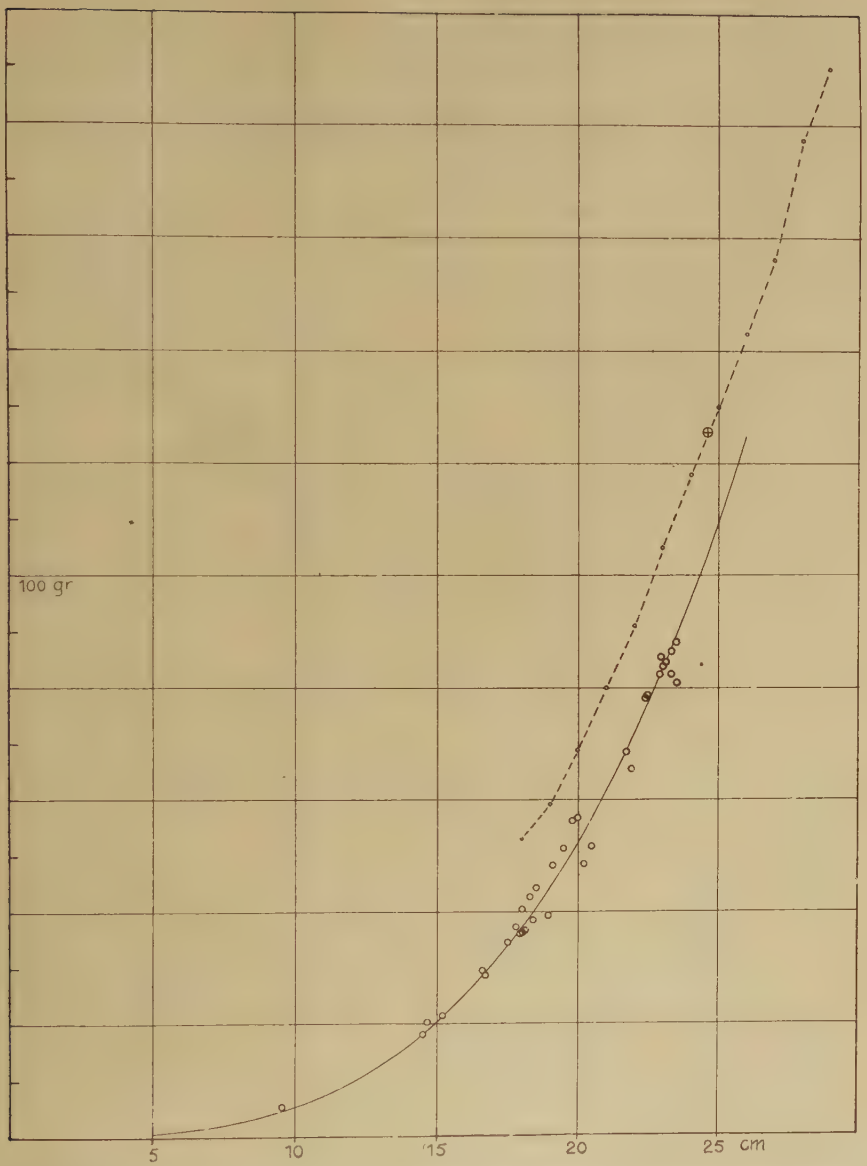

Fig. 10. The relation between length (abscissa) and weight (ordinate) for the oceanic young herring from autumn 1927 (dotted line) compared with the same relation for young herring caught off the coasts (thick line and circles).

In addition to the characteristic features of the oceanic young herring already described, the results as to weight deserve a brief discussion. In order to characterize the herring in this respect it is necessary to institute a basis for comparison; as such has been chosen a length-weight

relation which was worked out some time ago for the young herring occurring along the coast. This relation which is not a cubic parabola, but is somewhat steeper ($W = kL^{3\cdot3}$) seems to be closely applicable to young herring caught in the summer and autumn, at any rate as regards the group between $L = 15$ and $L = 25$ cm. This relation is given in Fig. 10, together with the central position for the samples for which it is calculated. If we examine this, we see that the function line should be regarded as a schematic expression for a position and the course of a zone within which the length-weight points find their place in a system of coordinates.

In the figure is plotted the central position for the material from the autumn of 1927, and from this a line connecting the points which give the average weight for each cm.-group in the material.

It will be seen that the position for the young oceanic herring lies far outside the zone within which are found all the samples of young coastal herring. The weight of the oceanic young herring is, when the same length group is compared, considerably greater than the weight of the young coastal herring. This difference in weight does not mean that the sexual organs of the oceanic herring were a little larger than the organs of the infantile coastal herring; the difference in weight is too great for this. Neither does it seem to be determined by any difference in the fat content. It is perhaps correct for the time being to regard the relation as an expression of the fact that the oceanic young herring have passed into another physiological state than that in which the infantile young herring are. Further investigations must show whether this length-weight relation can serve as a useful indicator for distinguishing between the two phases in the development.

That this phase in the development of the young herring should be characterized as an oceanic stage is clear, first and foremost from the fact that shoals of the group are so little in evidence along the Norwegian coast. It is very difficult to understand why the fishermen see so little of these herring unless one assumes that they regularly keep away from the coastal waters.

In addition, however, we possess some more direct observations which show that herring, which in all probability belonged to the oceanic group, were caught in the summer of 1925 in the entrance of the Skagerak, at the same time as similar herring also appeared along the west coast of Norway.

The samples sent us from the Skagerak for examination contained chiefly fish of the 1923 and 1922 year-classes. The growth history of these two year-classes proved to be so characteristic, and so different for the year-classes, that the growth calculations could be used for testing the

hypothesis that these samples of herring were young herring belonging to the Norwegian race. Fig. 11 shows in graphic form the results of the growth measurements which were available for this investigation. It is the average values for the annual increment of growth, calculated

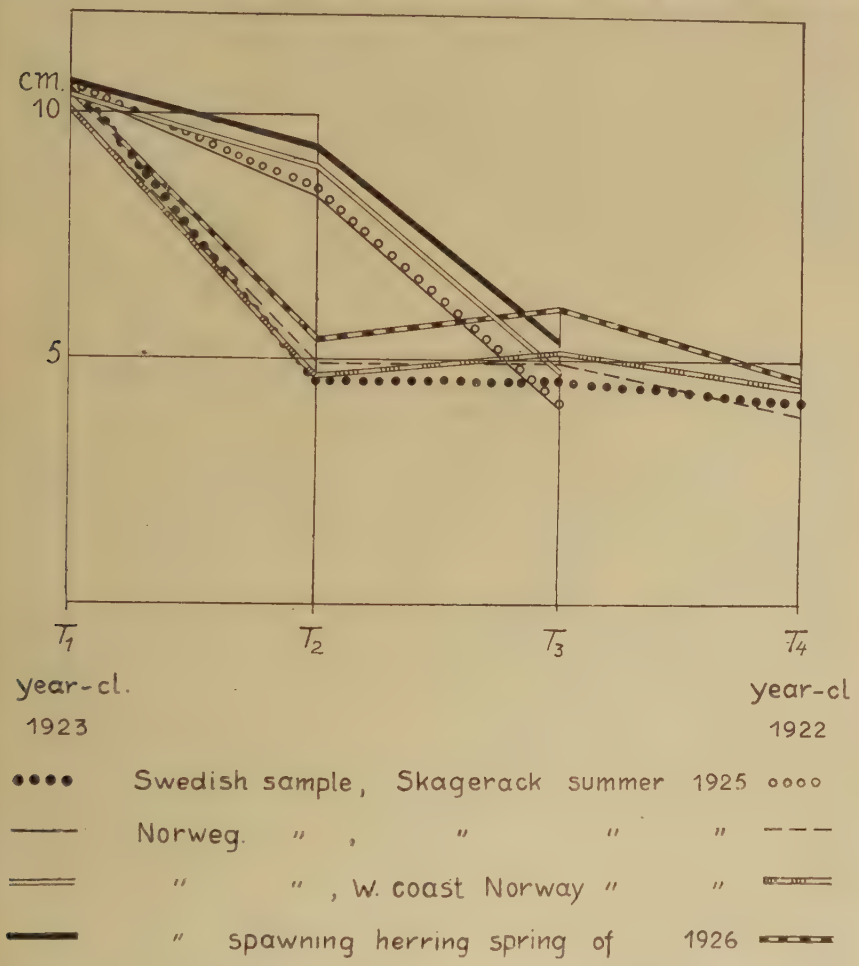

Fig. 11. Curves showing the mean annual increment of growth (T) in herring of the 1922 and 1923 broods in samples of oceanic young herring from summer 1925 and in samples of spawning herring from spring 1926.

according to scale measurements, that are presented, and the material consists of the Skagerak samples and the sample from the west coast of Norway, all from the summer of 1925. Further, there is included a sample from Swedish fishing experiments in the entrance of the Skagerak in July 1925, and finally the individuals of the two year-classes, which in the spring of 1926 had become spring herring ready to spawn.

The Swedish sample which was very kindly placed at our disposal by Dr. K. A. ANDERSSON has proved to be of great value in these investigations. For a number of countings of vertebrae had been carried out for this sample, and with the aid of these and the growth calculations, it has been possible to coordinate all the observations in a way which might, by a metaphor, be termed biological triangulation.

As is shown in Fig. 11, the marked difference in the growth history of the two year-classes appears in all the samples. There are two definite and different courses in the path traced by the curves, the one characteristic for the 1923 year-class and the other for the 1922 year-class. Such an extraordinary coincidence affords strong evidence that all the samples have an internal connexion.

Also numerically these observations indicate that the herring in all the samples belong to the same race, since the growth figures for each year-class show a great resemblance between the samples. The greatest difference lies in the fact that the values for the adult herring from the spring of 1926 are the highest for both year-classes. This is exactly what was to be expected when we take into account the fact that the larger fish in a year-class are the first to become adult and ready to spawn. All the investigations indicate that neither the younger fish in the samples of adult herring nor the older fish in the samples of unripe herring can be regarded as representative of their year-class as a whole. They have a biological or a physiological bias, each in its own direction.

The number of vertebrae for the Swedish herring shows for Vert. S. an average of 57.2 for year-class 1923 and 57.3 for year-class 1922. The corresponding numbers from Norwegian material of unripe herring in the summer of 1927 are 57.1 and 57.2 respectively. For the material of spawning herring from the spring of 1928 the figures were 57.4 and 57.1 respectively. Even though these figures alone are no certain proof, they do lend support to the assumption that the herring in the Skagerak belonged to the Norwegian race. Apart from the Norwegian herring which have previously been encountered in the Skagerak, it is unlikely that there is any other race of herring possessing a higher number of vertebrae than 57 which could come into the question here.

Which area in the sea it is that the oceanic Norwegian herring mainly frequent, these investigations still leave uncertain, and there are altogether only a few data on which to base a hypothesis.

The slight information we possess, in the form of reports from fishing experiments and the like, points to the region to the north-east of the Faroe Islands as a possible central area for the group of young herring. But no definite theory can be built on this basis, as these fishing experiments were carried out prior to the time when it was possible to identify

the captured herring as Norwegian young herring. This question as to their distribution must therefore remain in abeyance until fresh observations can be made. Only one thing seems to be indicated by the material which up to the present is in our possession, namely that the young herring, when they abandon the coast, can enter upon extensive migrations. The samples of herring from the Skagerak, which have been examined, contained individuals on the scales of which the winter rings had an appearance which corresponded very slightly to what one sees on the scales of the coastal herring from the southernmost part of Norway, but was very similar to what one sees in the herring from the north of Norway. The same was the case to an equally marked degree in the older herring in the material from the summer of 1927.

4. Some Consequences of the Theory, in Relation to the Fisheries and the Main Features in the Life History of the Norwegian Herring.

The results described in the foregoing must, together with others, affect our judgment as to the previously mentioned demand for the protection of the young coastal herring. They must lead to the conclusion that protection is unnecessary for the stock, and that it could not be hoped that a protection of the small herring would result in a larger stock of larger "fat herring" in the coastal waters. One is forced to assume that the herring would abandon the coastal waters when it suited them, independently of whether or not they had previously been the object of fishing operations.

Further, the results tend to strengthen the impression given by the statistics of the Norwegian herring fisheries, namely that the presence of the large "fat herring" in the coastal waters and in the fiords ought not to be looked upon as something which may be expected every year. It looks more as if the so-called "large fat herring years" occur when the oceanic group of herring, or portions of them, are driven to the coast as a consequence of circumstances, which at the present moment are unknown, or when the departure from the coast in order to take up an oceanic existence is, so to speak, delayed. In the former case the captured "fat herring" would be of average size and weight at least 100 grams each when salted, whilst in the latter case the herring would be considerably smaller. It seems that both these alternatives can occur, the latter when the individuals of the year-class in question have grown up slowly. That the "fat herring" fisheries under these circumstances must undergo great fluctuations, both as regards quantity and as regards the size and quality of the captured herring, seems unavoidable, especially

Fig. 12. Schematic presentment of the chief features in the life history of the Norwegian herring.

A. Arrival of the spawning herring at the spawning grounds in two main groups, firstly the older spawners and then the recruit-spawners, during the season January—April.

B. Dispersal of the year's fry along the entire coast.

C. Sojourn off the coast in the herring's second year of life.

D. Departure from coast, and transition to the oceanic stage, in the third year of life, of the herring which have lived along the southern part of the western coast.

Fig. 13. Continuation of Fig. 12.

E. Departure from coast and transition to the oceanic stage, mainly in the fourth year of life, of the herring which have lived further north along the coast.

F. Oceanic stage. Duration according to circumstances from one to three years, age of herring between two and six, possibly seven years.

G. Abandonment of the oceanic stage, after sexual development, by the herring which will become sexually mature at the coming spawning season.

H. Yearly circulation of the adult herring between the spawning places and the summer haunts.

when the effect of the fluctuations in the abundance of the year-classes is added.

In respect of our general conception of the life history of the Norwegian herring, the results have led to a more coherent piecing together of the separate fragments of knowledge which we have gradually acquired, and to a comprehension of certain features the significance of which was not immediately apparent.

With the aid of the investigations discussed here, it is possible to draw up an outline sketch which shows, I hope, the outstanding general features in the life history of the Norwegian herring. As a help to this end the schematic plates reproduced in Figs. 12 and 13 have been compiled.

If we begin with the spawning, which is most intensive on the southern part of the west coast, the observations show that just before spawning takes place there must be two contingents of herring on their way to the spawning places (see Sketch a).

The one contingent, which is regularly noticed to be first and most abundant, contains the older spawners, herring which have spawned in previous years. This contingent of herring, which contains the oldest and largest individuals of the race, is found by the fishermen first of all some distance to the north of the main spawning grounds, and some time before the individuals are ready to spawn.

The second contingent is not usually noticed to any extent before it appears on the spawning grounds proper. The individuals in this group are all smaller and younger and they become ready to spawn rather later than the bulk of the older spawners. These are the previously mentioned recruit-spawners.

Spawning begins, according to our experience, in February, and does not end until the first half of April, the chief spawning, however, ending before March 20th. As the herring eggs take about 24 days to hatch out, we may reckon that most of the larvae are hatched before the beginning of May.

We possess unfortunately very few observations as to the herring fry and the fate of the smallest metamorphosed "small herring". It is supposed that their distribution is due, at any rate to a great extent, to their being transported with the currents. It is certain in any case that they are found in the course of the summer in the fiords and the "Skærgaard" on the west coast, and somewhat later more to the north, right up in the north of the Finmark (see Sketch b).

The herring appear to spend the second year of their lives in the coastal waters without making any extensive migrations (see Sketch c).

It has been observed regularly that whereas the first year's growth does not differ much in herring whose haunts are along the west coast, and in herring which have gone farther north, this difference becomes more marked in the second year of their life, and the result is that herring two years of age along the west coast become larger than those of the same age in the north.

This difference in growth is presumably responsible for what happens in the next year, the herrings' third year of life. They disappear from the fishermen's catches on the west coast, but they occur regularly in the catches in the north and often constitute the bulk of them (see Sketch d). Various observations indicate that not all the herring in their third year in the north remain near the coast, but that a portion of them act like those farther to the south and disappear.

In the next year two things may happen with the herring which have not disappeared. Either they can (practically) disappear (see Sketch e), and this seems to happen most often, or the same thing can happen as in the previous year, i.e. that some go, while others remain. The latter alternative occurred in 1907, and has occurred also this year (1928), and in both these most pronounced cases the growth of the individuals remaining behind has been slow.

It is in the third and fourth years of their lives, therefore, that the herring adopt the oceanic mode of life. It is supposed that this transition is determined physiologically, and that sexual activity is the effective agent. Moreover, the observations justify us in assuming that it is the size attained rather than age which determines when this shall take place. According to this assumption, the necessary consequence is that these phenomena occur at a younger age in the south than in the north, and that the year-classes whose growth is slow act differently from the rapidly growing year-classes.

The duration of the oceanic stage must also vary according to the individual history of the herring. For some individuals it may be one year, for others two or three (see Sketch f). It is during this stage that the herring develop towards first maturity.

Each year, at which time is not known, this group of oceanic "young herring" must be split up into two groups (see Sketch g), since the individuals which will become ready to spawn in the coming spring must separate from the individuals which will not, and which must wait perhaps one year, perhaps two, until this takes place. In the fullness of time the group which has split off arrives on the spawning grounds as recruit-spawners, and, as far as they are concerned, this cycle in their life history is completed.

It is not yet quite certain what happens to the herring in the course of the year after they have appeared upon the spawning grounds as recruit-spawners. But if they at once join the older spawners (and it is here that uncertainty prevails) they set out on a long migration which is shown (again schematically) in Sketch h (which thus for the time being holds good for older fish of the Norwegian race of herring). The migration moves northwards and is marked by the following stages: in May—June the herring are on a level with Lofoten, in July they have been observed off Bear Island, in August—September off Spitzbergen, in October again on a level with Lofoten, and in the winter months farther to the south.

During this annual and very extensive migration the herring rapidly undergo a radical process of regeneration after spawning. Already in May, less than two months after spawning has taken place, the herring are encountered to the south of Lofoten at that point where the arrow to the extreme right in Sketch h ends. They are then lean, but completely gorged with *Calanus*. During a stay I made there in 1919, I had occasion to observe how the herring in a short time were capable of consuming great quantities of food and converting it into fat. So intensely active were the digestive enzymes during this period that the herrings split along the stomach a few hours after capture, and the workmen engaged in salting them soon got the skin of their hands damaged and had to cease work. We possess information from herring oil factories to the effect that the herring literally increase their fat content day by day by nearly 1 per cent.

The further fate of the adult herring is known, partly from observations made during a stay at Bear Island in July 1914, but especially from observations and the material acquired during the expedition which in recent years, under the direction of my colleague, the consultant Th. Iversen, have been made in the waters in the vicinity of Spitzbergen. During these cruises on several occasions cod were caught, in whose stomachs were found herring scales and in part whole herrings. The scales bore such an unmistakeable resemblance to the scales from the samples of Norwegian spawning herring that there can scarcely be any doubt as to their belonging to the same race of herring which each year appears off the west coast of Norway. These observations may with a high degree of certainty be connected with previous observations on the occurrence of the adult herring, and indicate presumably the northern limit of the adult herring's annual migrations.

Oberflächensalzgehalt im südlichen Teil der Nordsee.

(Monatskarten, Monats- und Dekaden-Abweichungen).

Von

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§ 1. Ein von dem Permanenten Internationalen Ausschuss für Meeresforschung in 1927 eingesetztes Sub-Komitee wurde beauftragt, eine Arbeitsmethode für die Berechnung des mittleren Salzgehaltes pro Monat oder pro Dekade für die Oberfläche der Nordsee zu entwerfen.

Im Anfang hielt das Komitee es für ratsam mit der Berechnung der Jahresmittelwerte und der Bestimmung der mittleren Jahresisohalinen anzufangen, um nach dieser Vorarbeit das Gebiet in »natürliche Felder« zu verteilen, für welche die Beobachtungen pro Monat oder pro Dekade gesammelt und zu Mittelwerten verarbeitet werden sollten. Als Mitglied dieses Komitees wurde der Verfasser gebeten, die vorläufige Bearbeitung mit Hilfe des Personals des Kön. Niederl. Meteor. Instituts zu unternehmen, was den südlichen Teil der Nordsee und das holländische Material anbelangt.

Das Komitee hielt später eine vorläufige Berechnung der Jahresisohalinen und eine Einteilung in »natürliche Felder« nicht mehr für notwendig. Die schon angefangene Arbeit wurde jedoch von mir und dem ersten Assistenten, Herrn V. P. van Halm, fortgesetzt. Die Arbeitsmethode führte zu einer vorhergehenden Berechnung der Monats- und Dekadenmittelwerte und der Zusammenstellung von Monatskarten. Um diese letzteren zu vervollständigen, sind nicht nur niederländische, sondern auch ausländische Messungen benutzt.

Vielen Dank sind wir dem Fisheries Laboratory zu Lowestoft schuldig, das die Monatsmittel der englischen Feuerschiffe in diesem Teil der Nordsee zu unserer Verfügung stellte.

§ 2. Beobachtungsgebiet und Beobachtungen. Das untersuchte Gebiet liegt zwischen der niederländisch-belgischen und der eng-

lischen Küste und wird im Norden und Süden begrenzt von den Parallelen 53°30′ und 51°0′ N. Auf der Karte Fig. 1 sind die Gebiete mit einer Tiefe von weniger als 20 m mit punktierten Linien angegeben. Zugleich findet man hier die Stelle der Feuerschiffe, für welche Monats- und Dekadenmittel berechnet wurden.

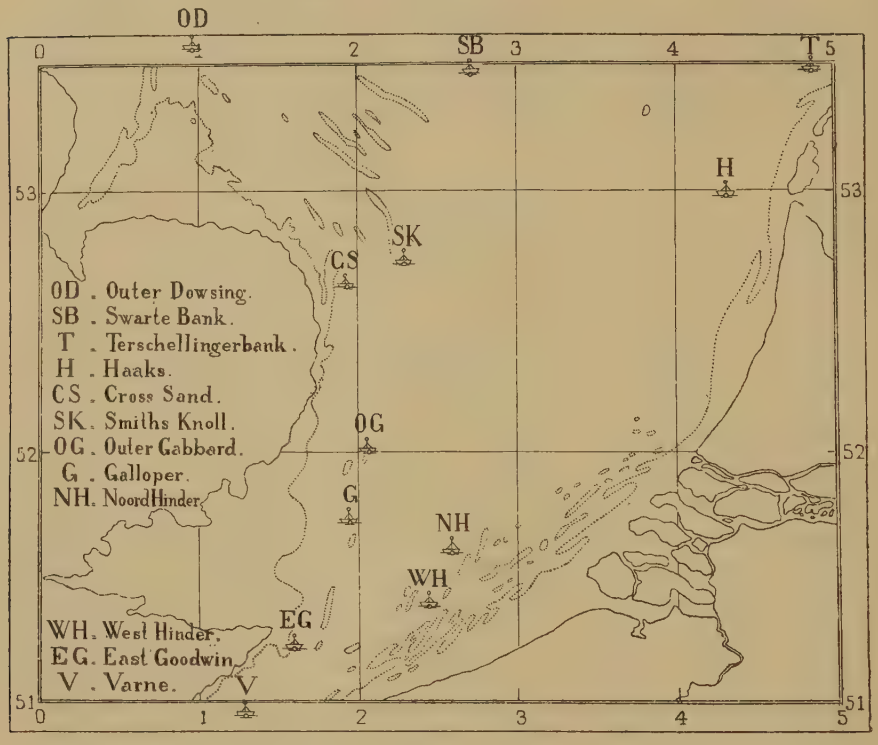

Fig. 1.

Das Beobachtungsmaterial umfasst:

A) Drei niederländische Feuerschiffe.
Acht britische Feuerschiffe.
Ein belgisches Feuerschiff.

B) Die Stationen der Jahre 1906—1914 a—d und g—u, die mittleren Beobachtungsstellen nach dem Kriege (1921—1926) A—G und die Station H (1921—1923).

C) Die zerstreut liegenden Beobachtungen vor und nach dem Kriege im nordöstlichen Teil der Nordsee östlich von 3° Länge und nördlich von 53° Breite. Die Felder von 15′ × 15′ mit mehr als 5 Beobachtungen wurden numeriert 1—8.

Die *sub* B und C genannten Stationen und Felder wurden auf der Karte Fig. 2 notiert.

§ 3. Genauigkeit der Beobachtungen und Verarbeitungsmethode. Der Salzgehalt wurde mittelst Chlortitrierung bestimmt. Die von den niederländischen Feuerschiffen und auf den festen Stationen

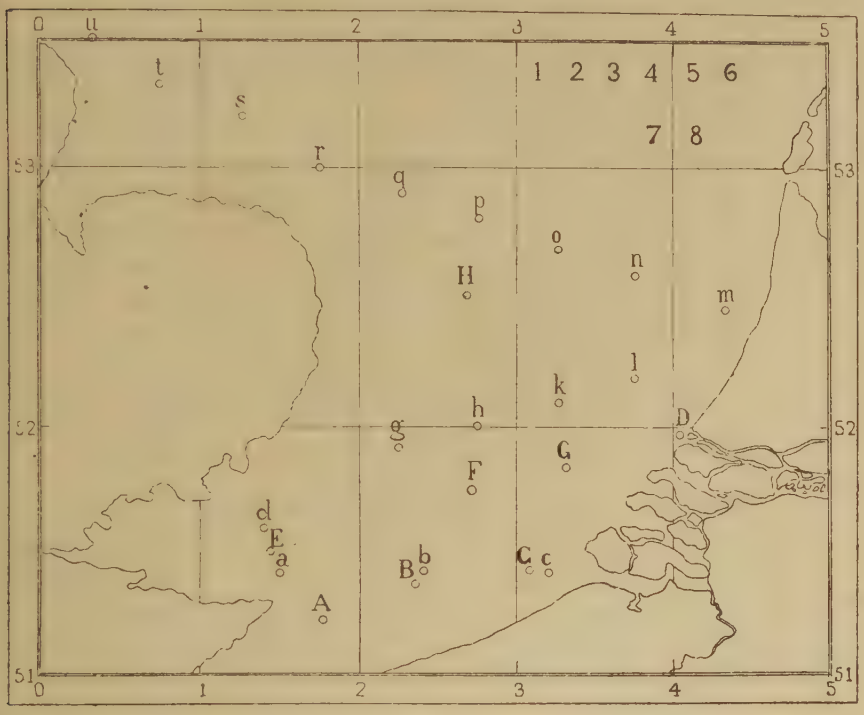

Fig. 2.

a—u für jede Dekade gesammelten Proben wurden zusammengefügt und von dem Gemisch der Salzgehalt bestimmt. Dann und wann wurden jedoch die einzelnen Proben kontrolliert.

Mit den Proben der Stationen A—G geschah dasselbe in dem Sinne, dass die Beobachtungsstellen für jede Station in den meisten Fällen nicht weiter als 15′ aus einander liegen.

Die Monatsmittelwerte der Feuerschiffe (Tabelle 1) verdienen viel Vertrauen, nicht nur wegen der grossen Anzahl Messungen, sondern auch weil es sich hier um feste Stationen handelt.

Die mittlere Anzahl Proben pro Monat und für die Perioden, während welcher beobachtet wurde, findet man in Tabelle 2. Falls die Beobachtungsperiode zu kurz war und wir über mehrere Daten eines in der Nähe

Tabelle 1. Salzgehalt Feuerschiffe.

Monat	51°36′ N 2°36′ E Noord Hinder	52°58′ 4°19′ Haaks	53°29′ 4°52′ Terschellingerbank	50°56′ 1°17′ Varne	51°13′ 1°36′ East Goodwin	51°23′ 2°27′ West Hinder	51°44′ 1°58′ Galloper	52°0′ 2°4′ Outer Gabbard	52°38′ 1°56′ Cross Sand	52°43′ 2°17′ Smith's Knoll	53°28′ 2°44′ Swarte Bank	53°34′ 0°59′ Outer Dowsing
J. . . .	**34.82**	34.32	33.75	34.99	34.86	34.40	34.83	34.79	34.08	34.35	34.50	34.54
F. . . .	.67	.32	.38	*.87*	.73	*33.81*	.88	.83	33.68	.27	*.42*	.38
M . .	63	.31	.49	35.01	*.72*	.97	.70	.64	*.56*	.12	.45	.47
A. . . .	*.44*	.01	.24	34.90	.80	.82	.68	.85	.74	*.06*	.43	.42
M. . .	.56	*.00*	.19	.98	.80	34.16	*.58*	.79	.91	.07	.46	*.36*
J. . . .	.53	.13	*.10*	.94	.79	.33	.75	.65	.96	.22	.52	.37
J. . . .	.60	.06	.31	.96	.86	.39	.68	*.59*	.92	.18	.63	.38
A. . . .	.67	.30	.48	.94	.89	.43	.88	.73	34.05	.18	.66	.37
S. . . .	.64	.30	.74	.96	.93	.22	.92	.80	.15	.26	.60	*.36*
O. . . .	.62	**.51**	.73	35.00	35.03	.46	35.01	.95	.21	.36	.58	.44
N. . .	.76	.50	.93	.00	**.04**	.54	34.94	.95	.24	**.49**	**.68**	.57
D. . .	.80	.46	**.96**	**.03**	.03	**.56**	**35.08**	**35.07**	**.31**	.41	.66	**.62**

liegenden Feuerschiffes verfügen konnten, wurden die Monatsmittel korrigiert. Hierzu bemerken wir folgendes:

a) Die Mittelwerte für Galloper wurden bestimmt durch Anwendung einer Korrektion bei dem berechneten Monatsmittel von 1921. Diese Korrektion wurde den Monatsabweichungen von Varne für dieses Jahr entnommen.

b) Die Mittelwerte für Outer Gabbard wurden bestimmt durch Anwendung einer Korrektion bei dem berechneten Monatsmittel für die Jahre 1913, 1914, 1920 und 1921 (für Januar auch 1922). Diese Korrektion wurde den Abweichungen von Smith's Knoll für diese Jahre entnommen.

c) Die Mittelwerte für Swarte Bank wurden bestimmt durch Anwendung einer Korrektion bei dem Monatsmittel der *sub* b. genannten Jahre.

Tabelle 2. Mittlere Anzahl Wasserproben pro Monat und Beobachtungsjahre der Feuerschiffe.

Feuerschiff	Mittl. Anzahl Proben pro Monat	Beobachtungsjahre
Noord Hinder	28	1906-1914, 1921-1926[1])
Haaks	29	1906-1914, 1921-1926[2])
Terschellingerbank	28	1906-1914, 1923-1926[3])
Varne	10	1905-1922[4])
East Goodwin	7	1905-1910, 1913-1914, 1920-1922[5])
West Hinder	7-8	1906-1911
Galloper	10-11	1921
Outer Gabbard	9	1913-1914, 1920-1922[6])
Cross Sand	10-11	1913-1915, 1920-1922[7])
Smith's Knoll	15	1910-1914, 1920-1922[8])
Swarte Bank	11	1913-1914, 1920-1922[9])
Outer Dowsing	11	1913-1914, 1920-1921[10])

[1]) 1906, die letzten 2 Monate.
[2]) 1914 und 1921, bez. 3 und 7 Monate.
[3]) 1914, die Monate Januar bis August.
[4]) 1905, die letzten 3 Monate.
[5]) 1905, 1910, 1920 und 1922, bez. 3, 6, 9 und 1 Monate.
[6]) 1913, 1914, 1920 und 1922, bez. 10, 10, 4 und 1 Monate.
[7]) 1913, 1915 und 1922, bez. 10, 6 und 1 Monate.
[8]) 1910, 1914 und 1920 unvollständig, jedoch mehr als 6 Monate.
[9]) 1914, 1920 und 1922, bez. 9, 9 und 1 Monate.
[10]) 1914 und 1920 unvollständig, jedoch mehr als 6 Monate.

Diese Korrektion wurde den Abweichungen von Haaks und Smith's Knoll für diese Jahre entnommen.

Die angewandten Verbesserungen geben wir in Tabelle 3.

Obgleich die Anzahl Beobachtungsjahre für Outer Dowsing auch nicht genügt, wurde hier von Anwendung einer Korrektion, den Daten von Smith's Knoll entnommen, abgesehen. Outer Dowsing liegt in der von Norden kommenden Strömung, Smith's Knoll dagegen mehr in einem Übergangsgebiet. Wir kommen hierauf noch später zurück.

Die mittlere Anzahl Proben pro Monat ist noch bedeutend für die

Tabelle 3. Korrektionen für die Salzgehalt-Monatsmittel der Feuerschiffe Galloper, Outer Gabbard und Swarte Bank.

Monat	Galloper	Outer Gabbard	Swarte Bank
J.	— 0.14	— 0.13	— 0.13
F.	— 0.05	— 0.09	+ 0.05
M.	— 0.09	0	+ 0.05
A.	— 0.18	+ 0.05	+ 0.12
M.	— 0.10	+ 0.05	+ 0.12
J.	— 0.07	0	+ 0.12
J.	— 0.05	0	+ 0.12
A.	— 0.11	0	+ 0.12
S.	— 0.17	0	+ 0.12
O.	— 0.17	+ 0.05	+ 0.06
N.	— 0.22	— 0.02	+ 0.06
D.	— 0.21	+ 0.06	+ 0.06

Stationen a—c, nämlich 35; für d, m und p ist die Anzahl 9 bis 11, und für die übrigen 5 bis 8.

Die Verarbeitung des Beobachtungsmaterials der Dampfer zeigte zuweilen Schwankungen im Salzgehalt der aufeinander folgenden Dekaden, die in den betreffenden Gebieten schwerlich erklärt werden könnten durch plötzliches Auftreten salzärmeren Wassers und möglicherweise verursacht wurden durch Verwechselung von Wasserproben. In diesen einzelnen Fällen wurden diese Daten nicht eingetragen und wo Resultate der Feuerschiffe zur Verfügung standen, fielen die betreffenden Stationen aus. Dies war der Fall mit den Stationen e und f.

Vergleicht man jedoch in Tabelle 4 den jährlichen Gang an den verschiedenen Stationen und die allmähliche Verschiebung der Extremwerte von a bis n, dann deutet die Übereinstimmung auf eine befriedigende Genauigkeit. Für die Stationen im Norden zeigen die Jahreskurven

Tabelle 4. Salzgehalt, Stationen a—u.

	51°24′N 1°30′E	51°24′ 2°24′	51°24′ 3°12′	51°36′ 1°24′	51°54′ 2°15′	52° 0′ 2°45′	52° 6′ 3°15′	52°12′ 3°45′	52°27′ 4°18′	52°36′ 3°45′	52°42′ 3°15′	52°48′ 2°45′	52°54′ 2°15′	53° 0′ 1°45′	53°12′ 1°15′	53°18′ 0°45′	53°30′ 0°18′
Monat	a	b	c	d	g	h	k	l	m	n	o	p	q	r	s	t	u
J.	34.64	34.53	32.01	34.68	**35.05**	34.77	**34.75**	34.14	33.05	**34.74**	34.59	**34.64**	**34.77**	34.64	**34.58**	34.46	34.03
F.	.45	.32	31.25	.75	34.87	.82	.63	.25	32.95	.37	.55	.55	.56	*.28*	.52	.27	***33.92***
M. . . .	.41	.49	.21	.58	.53	.47	.17	33.32	.94	.37	.64	.48	.34	.48	.49	*.25*	34.16
A.	*.38*	*.21*	30.73	*.32*	.67	.61	.31	.41	.91	*.21*	.66	.51	.61	.49	.53	.28	33.99
M. . . .	.51	.27	*.63*	.44	*.52*	*.44*	*.12*	.58	*.44*	.29	.53	.43	.51	.53	.57	**.59**	34.16
J.	.52	.32	.83	.62	.58	*.44*	.20	*.30*	.69	.31	.61	.44	.43	**.65**	.46	.46	.10
J.	.69	.52	31.28	.45	.56	.51	.36	.62	.86	.45	*.42*	.46	.50	.59	.50	.41	.25
A.	.72	.42	.36	.64	.63	.49	.34	.87	33.31	.27	.60	.44	*.30*	.35	*.43*	.41	.18
S.	**.83**	.45	.82	**.88**	.74	.80	.58	34.07	.41	.50	.54	*.25*	.53	.55	.49	.46	**.32**
O.	.80	.40	.89	.83	.78	.69	.45	.00	.33	.51	**.67**	.46	.57	.49	.50	.47	.11
N. . . .	.80	.58	**32.27**	.72	.90	**.85**	.67	**.53**	.65	.55	.53	.59	.63	.55	.46	.45	.22
D. . . .	.65	**.68**	.14	.83	.81	.81	.71	.28	**.67**	.65	.64	.60	.54	.57	*.43*	.48	.14

Tabelle 5. Salzgehalt, Stationen A—G.

	51°13′N 1°47′E	51°22′ 2°21′	51°25′ 3° 4′	51°57′ 4° 3′	51°30′ 1°26′	51°45′ 2°42′	51°51′ 3°18′
Monat	A	B	C	D	E	F	G[1])
J.	35.04	34.61	32.29	*27.57*	34.69	34.90	34.36
F	.06	.62	.25	28.90	.63	77	.33
M.	34.93	.24	31.56	.82	.43	.86	33.98
A.	*.88*	*.07*	*.12*	.14	*.36*	*.42*	.84
M.	35.02	,27	.68	.16	.45	.46	*.78*
J.	34.92	.22	.78	27.74	.51	.68	.86
J.	.92	.30	32.04	28.99	.65	.62	.85
A.	**35.09**	.61	.91	29.49	.80	.69	.97
S.	.00	**.90**	**33.10**	30.19	.84	.65	34.32
O.	**.09**	.46	32.70	**.75**	.86	.67	**.45**
N.	.07	.35	.34	29.71	**.92**	**.80**	.19
D.	34.98	.16	.78	30.32	.85	.66	33.96

keinen einfachen Verlauf; die Eintrittszeiten der Extremwerte sind unregelmässig verteilt.

Tabelle 5 gibt die Monatsmittel der Stationen A—G. Die mittlere Anzahl Proben pro Monat beträgt für A, B und C 50—60, für D, E und F ungefähr 20 und für G 5 bis 11. Maxima und Minima stimmen, was die Eintrittszeiten anbelangt, gut mit den anderen südlichen Stationen

Tabelle 6. Salzgehalt, Station H.

Monat	β	λ	S ‰	Anzahl Proben
J.	52°.5 N	2°.7 E	**34.84**	9
F.	52°.5	2°.6	.77	9
M.	52°.5	2°.7	.66	14
A.	52°.6	2°.8	.76	5
M.	52°.6	2°.9	.82	6
J.	52°.4	2°.5	*.44*	6
J.	52°.5	2°.6	.57	5
A.	52°.6	2°.9	.50	7
S.	52°.5	2°.8	.46	3
O.	52°.5	2°.7	.64	6
N.	52°.5	2°.6	.58	7
D.	52°.5	2°.8	.82	3

[1]) 1921—1923.

Tabelle 7. Korrektionen für die Salzgehalt-Monatsmittel der Felder 1—8.

Monat	1	2	3	4	5	6	7	8
J.	..	..	..	—0.21	..	—0.16	..	—0.27
F.	..	..	..	..	—0.30	..	—0.29	..
M.	..	..	..	..	..	..	—0.33	—0.36
A.	..	..	..	..	..	..	—0.19	—0.25
M.	..	..	..	..	..	—0.26	..	..
J.	..	..	..	..	—0.33	—0.28	..	..
J.	..	..	..	—0.26	—0.16	—0.30	..	..
A.	..	..	..	—0.12	0	—0.27	..	..
S.	..	..	..	0	..	—0.10	—0.08	—0.02
O.	—0.06	+0.12	+0.17	..	—0.11	—0.06	—0.11	..
N.	..	—0.09	..	0	..	..	—0.27	—0.27
D.	..	—0.04	..	—0.05	..	—0.02	..	..

überein. Die Station D, die eine Ausnahme bildet, liegt in der Nähe der holländischen Küste, wo das Flusswasser wiederholt grosse Schwankungen im Salzgehalt verursacht. Für die Monatsmittel selbst ist die Übereinstimmung der beiden Stationen B und b weniger befriedigend.

Die Berechnung der Mittelwerte der Station G aus den Messungen der Jahre 1921—1923 geschah unter Anwendung einer Korrektion von minus 0.30 ‰. Diese Korrektion wurde den Abweichungen vom Jahresmittel von Noord Hinder für diese drei Jahre entnommen.

Tabelle 8. Salzgehalt, Felder 1—8.

Monat	1	2	3	4	5	6	7	8
J.	..	..	..	(34.89)	..	(34.69)	..	34.65
F.	..	..	..	..	(34.73)	..	34.72	..
M	..	..	..	..	..	..	34.86	34.74
A.	..	..	..	..	..	..	34.78	34.70
M.	..	..	..	..	..	34.47	..	..
J.	..	..	..	..	(34.59)	34.29	..	..
J.	..	..	..	34.50	34.54	34.64	..	..
A.	..	..	..	34.57	34.77	34.62	..	..
S.	..	..	..	34.56	..	34.47	(34.67)	34.82
O.	34.68	34.43	34.68	..	34.48	34.58	34.72	..
N.	..	34.65	..	34.75	..	..	34.72	34.53
D.	..	(34.73)	..	(34.74)	..	(34.76)	..	..

Auf dem Schiffsweg Esbjerg—Parkeston wurden nur die Messungen in der Mitte der Nordsee benutzt für die Jahre 1921—1923; Länge und Breite der vereinzelten Beobachtungsstellen laufen höchstens 15′ aus einander. Die mittlere Stelle für Station H ist deshalb nicht für jeden Monat dieselbe, wie aus Tabelle 6 hervorgeht. Die Berechnung der Salzgehalt-Mittelwerte dieser Station geschah unter Anwendung einer Korrektion von minus 0.30 ‰, ebenso den Daten des Feuerschiffes Noord Hinder entnommen. Die Gesamtzahl der Proben beträgt für jeden Monat 3 bis 14.

Zum Schluss sollen noch die zerstreut liegenden Messungen im nordöstlichen Teil des Gebietes betrachtet werden. Die Monatsmittel, berechnet für Felder von 15′ × 15′ stellten sich im Allgemeinen sehr hoch heraus. Ein Vergleich mit den für das Feuerschiff Haaks bestimmten Jahresmittelwerten zeigte denn auch, dass die Beobachtungsjahre der Felder 1—8 ungefähr alle sehr salzreich waren. Deswegen wurde eine Korrektion angewendet, den Daten dieses Feuerschiffes entnommen (Tabelle 7). Die in dieser Weise verbesserten Resultate geben wir in Tabelle 8. Die zwischen Klammern gedruckten Werte wurden berechnet aus 5 oder weniger Beobachtungen; die maximale Anzahl ist 13.

§ 4. Mittlere Monatsisohalinen. Die in der oben angegebenen Weise bestimmten Mittelwerte des Oberflächensalzgehaltes wurden auf 12 Einzelkarten eingetragen (s. S. 62—67) und bildeten die Grundlage für die Zeichnung der Isohalinen. In erster Linie wurde hierbei Rücksicht genommen auf die Mittelwerte der Feuerschiffe, dann auf die Resultate der Messungen auf den Schiffswegen zwischen Holland und England.

Die Konstruktion der Isohalinen bot wenig Schwierigkeiten; nur im NE des Gebietes, wo über wenig Messungen in den Feldern 1—8 verfügt wurde, konnte der Verlauf der 34.75-Isohaline nicht immer mit genügender Zuverlässigkeit festgestellt werden.

Der Jahresgang des Salzgehaltes ist, wie bekannt, hauptsächlich eine Folge der Wasserzufuhr aus Norden, der schottischen und englischen Küste entlang, und des Eintretens von Kanalwasser durch die Dover-Strasse. Dazu kommt noch die Flusswasserzufuhr aus den Themse-, Schelde-, Maas- und Rheinmündungen und aus der Zuiderzee. Wir werden die infolge dieser Komponenten monatlich auftretenden Schwankungen nicht alle besprechen, sondern nur einige Umstände näher betrachten.

Der Isohalinenabstand ist nicht konstant; von 34 ‰ bis 35 ‰ wurde dieser für jede 0.25 ‰ gezeichnet. Die Anzahl Messungen macht eine weitere Unterteilung spekulativ. Für das Küstenwasser wurden die Kurven in Abständen von 1 ‰ eingetragen, wobei 32 ‰ als Grenze be-

trachtet wurde. Die Schwankungen innerhalb dieser Kurve sind so unstetig und die Anzahl Messungen ist so gering, dass diese nicht weiter in Betracht kommen.

Das Gebiet mit höchstem Salzgehalt liegt, wie im Norden der Nordsee[1]), mehr nach Westen infolge des Einflusses der durch Holland strömenden Flüsse, deren Kapazität grösser ist als die an der Westseite.

Aus dem Isohalinenverlauf in der Nähe der Küste von Norfolk darf man schliessen, dass das Wasser in dieser Gegend von Februar bis Mai nach Nordosten und Norden fliesst. Eine kleine Ausbiegung der Kurve in Juni bis August deutet in derselben Richtung, während in den beiden folgenden Monaten die Abfuhr mehr nach Osten stattfindet. Sobald in November bis Januar die Strömung von salzreichem Wasser aus Süden am kräftigsten wird, ziehen sich die Isohalinen nach der englischen Küste zurück.

Van Everdingen[2]) weist auf das Bestehen dieser nordöstlichen Abzweigung schon auf Grund der Temperaturverteilung an der Oberfläche in den aufeinander folgenden Dekaden.

In den von Böhnecke[3]) konstruierten Vierteljahrskarten der ganzen Nordsee kommt diese Abzweigung vor als ein Teil eines cyklonalen Wirbels, der von diesem Autor als der südwestliche Doggerbankwirbel bezeichnet wird.

Die Resultate einer systematischen Untersuchung von Lumby und Carruthers, welche vor kurzer Zeit im Journal du Conseil veröffentlicht wurden[4]), zeigen ebenso eine Ausbiegung der Isohalinen nach NE in der Nähe von der Norfolk-Küste, und in den auf diesen Daten sich stützenden Strömungskarten in einer Tiefe von 20 m tritt der von Böhnecke genannte Wirbel deutlich hervor.

Als zweite Besonderheit nennen wir die in fast allen Karten vor-

[1]) Vor 20 Jahren wurde hierauf schon von Thompson hingewiesen:
d'Arcy Wentworth Thompson. The salinity of the North Sea. North Sea Fisheries Investigation Committee. Fourth report (Northern area).
Vergl. auch: M. Knudsen. The salinity of the North Sea and adjacent waters. Rapp. et Proc.-Verb., VI, Annexe A, 1906.

[2]) Dr. E. van Everdingen. Kon. Nederl. Meteor. Instituut. N° 102. Mededeelingen en Verhandelingen. 3. Oberflächentemperaturbeobachtungen in der Nordsee. Sept. 1903—Aug. 1904. Mededeelingen en Verhandelingen. 10. Oberflächentemperaturbeobachtungen in der Nordsee, II. Sept. 1904—Aug. 1905.

[3]) Dr. G. Böhnecke. Salzgehalt und Strömungen der Nordsee. Veröffentl. des Instituts für Meereskunde, N. F., A. Heft 10, 1922. Vergl. auch: Atlas für Temperatur, Salzgehalt und Dichte der Nordsee und Ostsee. Deutsche Seewarte Hamburg, 1927.

[4]) J. R. Lumby and J. N. Carruthers. An Experiment dealing with the Interpretation of Salinity Distribution Charts. Journal du Conseil, Vol. III, N° 2.

kommende Einbiegung der Isohalinen in der Themsemündung. Wahrscheinlich bildet auch hier das im Süden herausströmende salzarme Wasser einen cyklonalen Wirbel mit dem central nach Westen hineinfliessenden Kanalwasser. Viele von den obengenannten Dekadenkarten von Van Everdingen[1]) zeigen eine gleiche Einbiegung der Isothermen. Nur wenn der Temperaturunterschied zwischen Nordsee- und Flusswasser gering ist, fällt die Übereinstimmung mit der Gestaltung der Temperaturverteilung naturgemäss aus.

Zum Schluss bemerken wir betreffs der Monatskarten noch Folgendes: Während der Monate März bis August ist der Einfluss der kontinentalen Flüsse am deutlichsten merkbar den Mündungen von Maas und Rhein gegenüber, und ein wenig nördlich davon. Das Gebiet mit mehr als 34.5 $^0/_{00}$ Salzgehalt wird zwischen 52° und 53° immer schmaler und endlich im Juni durchbrochen. Wahrscheinlich macht sich auch hier das von Westen her kommende englische Küstenwasser geltend, wie wir später sehen werden.

Die Messungen an den holländischen Terminstationen H_8, H_8A und H_9 zeigen keinen oder nur geringen Unterschied zwischen dem Salzgehalt in den tieferen Schichten und dem an der Oberfläche. Der Durchbruch findet also bis zum Boden statt. Nur in der Nähe der holländischen Küste nimmt der Salzgehalt mit der Tiefe bedeutend zu; weiter entfernt ist die Mischung von Nordsee- und Flusswasser bald vollkommen.

Nach August zieht die Isohaline von 34 $^0/_{00}$ sich zurück nach der holländischen Küste, zu gleicher Zeit mit dem nördlichen Vordringen des Kanalwassers und der Erweiterung des Gebietes mit mehr als 34.75 $^0/_{00}$ Salzgehalt. Die mittleren Abstände in km der Isohaline von 34 $^0/_{00}$ von Hoek van Holland in den vier Jahreszeiten sind:

Jahreszeit	Abstand in km.
Winter	22
Frühjahr	44
Sommer	42
Herbst	27

Im Norden und Nordosten bleibt der Salzgehalt nach August noch ziemlich niedrig, wahrscheinlich spielt auch hier das von der Norfolk-Küste nach Osten und Nordosten fliessende salzarme Wasser eine Rolle. Im November zeigt sich jedoch in der Nähe vom Feuerschiff Terschellingerbank die Isohaline von 34.75 $^0/_{00}$ wieder.

Um zu prüfen, ob eine deutliche Beziehung besteht zwischen dem

[1]) l. c. **3** p. 24, **10** p. 12.

niedrigen Salzgehalt im Frühjahr und Frühsommer und der Flusswasserzufuhr der holländischen Küste, wurden die mittleren Monatsabweichungen vom Jahresmittel des Wasserstandes zu Nijmegen — einer Station am wichtigsten Rheinarm in einer Distanz von 150 km von der Küste — verglichen mit den Abweichungen des Salzgehaltmonatsmittels.

Untenstehende Tabelle enthält die Wasserstandsabweichungen in cm (a) und die Summe der Salzgehaltsabweichungen der Feuerschiffe Noord Hinder, Haaks und Terschellingerbank (b) in Tausendstel mit entgegengesetztem Zeichen.

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
a	+13	+49	+63	+80	+44	+28	—6	—35	—51	—70	—88	—27
b	+ 8	+ 2	+76	+70	+69	+48	0	—23	—41	—74	—77	—44
	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	J.

Nach Verschiebung um einen Monat stimmen die gefundenen Werte sehr gut überein. Der relativ zu hohe Wert des Salzgehaltes im Winter (besonders im März) muss auf den Einfluss der Winterstürme zurückgeführt werden, wodurch das salzreiche Kanalwasser weit nach Norden vordringt. Der Korrelationskoeffizient beträgt minus 0.936 ± 0.024.

Wenn die Änderungen in der Flusswassermenge die einzige wichtige Ursache bildeten für die in der südlichsten Nordsee auftretenden Schwankungen im mittleren Salzgehalt, sollten auch die Änderungen von Jahr zu Jahr dieselbe Beziehung zeigen. Um davon ein Bild zu gewinnen, wurden die jährlichen Abflussmengen von Rhein, Waal und Maas in kub.m/sec. bestimmt. Dies geschah mittelst Berechnung der Abweichungen des mittleren Wasserstandes an den Stationen Arnhem (Rhein), Nijmegen (Waal) und Venlo (Maas) für die Sommermonate während der Jahre 1906—1914 und 1921—1924[1]). Daneben wurden für die drei obengenannten holländischen Feuerschiffe die mittleren Abweichungen der Jahresmittelwerte vom normalen Salzgehalt berechnet. Wir geben die Resultate in Tabelle 9.

Obgleich die Schwankungen in den jährlichen Abflussmengen bedeutend sind, ist von einer Beziehung wenig zu spüren. Der geringe Salzgehalt in 1911 fällt sogar zusammen mit einer geringen Flusswasserzufuhr, während in den Jahren 1921 und 1922 bei nur geringem Unterschied im Salzgehalt die Abflussmengen bedeutend auseinander laufen.

Offenbar sind noch andere Ursachen wirksam, wovon in erster Linie

[1]) Dr. J. P. van der Stok. Kon. Ned. Meteor. Instituut, N° 102. Mededeelingen en Verhandelingen N° 4. Über Oberflächentemperaturen des Meereswassers unweit der niederländischen Küste.

Tabelle 9. Flusswasser und Salzgehalt.

Jahr	Flusswasser kub. m/sec.	Abw. Salzgehalt ‰
1906	1780	— 0.01
07	1750	+ 0.18
08	2075	+ 0.14
09	1800	+ 0.34
10	2725	— 0.24
11	1250	— 0.51
12	2000	+ 0.10
13	1975	— 0.21
14	2550	— 0.24
21	800	+ 0.22
22	2400	+ 0.37
23	1850	+ 0.32
24	2875	— 0.05

genannt werden muss der Einfluss der Schwankungen in der Zufuhr des Atlantischen Wassers. Bestimmung dieser Schwankungen wäre möglich mittelst Berechnung der jährlichen mittleren Schiffsstromversetzungen im N. Atlantischen Ozean oder in vorher festgestellten Gradfeldern dieses

Tabelle 10. Regendauer und Salzgehalt.

Noord Hinder			Noord Hinder		
Monat	Abw. S ‰	Abw. mittl. Regendauer in Stunden	Jahr	Abw. S ‰	Abw. mittl. Regendauer in Stunden
J.	+ 0.17	+ 9	1907	+ 0.09	—123
F.	+ 0.02	+ 1	08	+ 0.23	—187
M.	— 0.02	+22	09	+ 0.22	+ 73
A.	— 0.21	— 7	10	— 0.23	+ 88
M.	— 0.09	—16	11	— 0.59	+ 18
J.	— 0.12	—22	12	— 0.06	+109
J.	— 0.05	—11	13	— 0.21	— 35
A.	+ 0.02	—19	14	— 0.22	+ 54
S.	— 0.01	—13			
O.	— 0.03	+11			
N.	+ 0.11	+13			
D.	+ 0.15	+34			
Normalwert	34.65	59 Stunden	Normalwert	34.65	703 Stunden

Gebietes. Für diesen Zweck sollte jedoch das Beobachtungsmaterial der verschiedenen Institute vereint werden.

In Tabelle 10 geben wir für das Feuerschiff Noord Hinder die Abweichungen des Salzgehaltes in Tausendstel und der Regendauer in

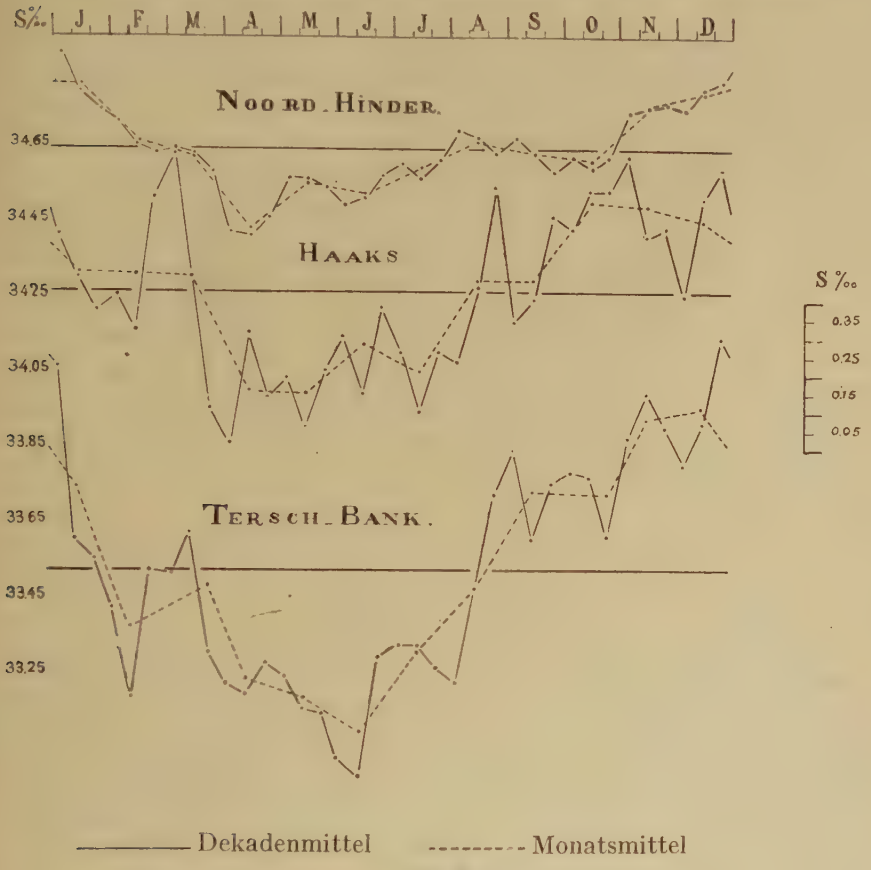

Fig. 3.

Stunden für jedes der Jahre 1907—1914 und die Abweichungen vom Monatsmittel dieser beiden Faktoren. Die Resultate zeigen keine einfache Beziehung zwischen lokalem Niederschlag und Oberflächensalzgehalt. Bei den Monatsabweichungen überwiegt scheinbar der Einfluss des Atlantischen Wassers, bei den Jahresabweichungen der des Regens.

§ 5. Dekaden- und Monatsmittel. In Fig. 3 konstruierten wir die Kurven der Dekaden- und Monatsabweichungen. Die Kurven wurden für dieselbe Basislinie gezeichnet; Noord Hinder hat den höchsten, Terschellingerbank den niedrigsten mittleren Salzgehalt. Je nachdem der Salzgehalt niedriger wird, wächst die Amplitude des jährlichen Ganges.

Station	Mittlerer Salzgehalt ‰	Amplitude ‰
Noord Hinder	34.65	0.38
Haaks	34.27	0.51
Terschellingerbank	33.53	0.86

Aus den Kurven geht hervor, wie verschieden die Mittelwerte von Dekade zu Dekade in der Nähe der Küste sein können (Haaks und Terschellingerbank). Für Noord Hinder sind die mittleren Dekaden-Schwankungen jedoch viel kleiner.

Die Messungen an dieser Station der Jahre 1907—26 ergaben für die Standard-Anomalie[1]) der Dekaden von Februar und August:

Februar			August		
I	II	III	I	II	III
0.43	0.33	0.29 ‰	0.41	0.44	0.46 ‰

Zwischen den Abweichungen der aufeinanderfolgenden Dekaden besteht offenbar eine enge Beziehung. Wir berechneten untenstehende Korrelationskoeffizienten:

Februar		August	
I—II	0.865 ± 0.045	I—II	0.923 ± 0.028
I—III	0.718 ± 0.087	I—III	0.907 ± 0.033

Um einen Überblick zu gewinnen über die Änderungen, die im Westen und Norden auftreten, wurden die Resultate der Tabelle 4 für die Stationen n—o, q—r und s—t vereinigt (vergl. Fig. 4). Die Kurven dieser drei Gruppen zeigen eine kleine Monatsamplitude und einen ziemlich hohen Salzgehalt. Die Monatskurve für n—o gleicht der für Noord Hinder; das Minimum fällt jedoch im erstgenannten Gebiet einen Monat später, was wieder mit Haaks übereinstimmt.

Die mittleren Schwankungen von Dekade zu Dekade sind für n—o bedeutend, wahrscheinlich infolge des Einflusses des holländischen Küstenwassers.

In dem Jahresgang der beiden anderen Gruppen können wir schon die Wirkung des von Nordwesten kommenden Wassers spüren[2]). Anstatt eines Minimums im Mai bildet sich hier im Frühjahr ein Maximum. Die

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[1]) $\sigma = \sqrt{\frac{\Sigma x^2}{n-1}}$; x = Dekaden-Abweichung, n = Anzahl Abweichungen.

[2]) Vergl. auch Dr. G. Böhnecke. Der jährliche Gang des Salzgehaltes in der Nordsee. Veröffentlichungen des Instituts für Meereskunde, N. F., A, Heft 15.

Lage der extremen Werte wird offenbar von Mischungsverhältnissen bestimmt.

Auch die Schwankungen von Jahr zu Jahr weisen darauf hin, dass wir uns hier in einem Übergangsgebiet befinden. Wir geben in Fig. 5 (S. 20) die Kurven der Schwankungen von Jahr zu Jahr für die Periode 1906—1914. An den Stationen Noord Hinder, Haaks und Terschellingerbank und in dem Gebiet h—k wird ein Maximum des Salzgehaltes in 1909

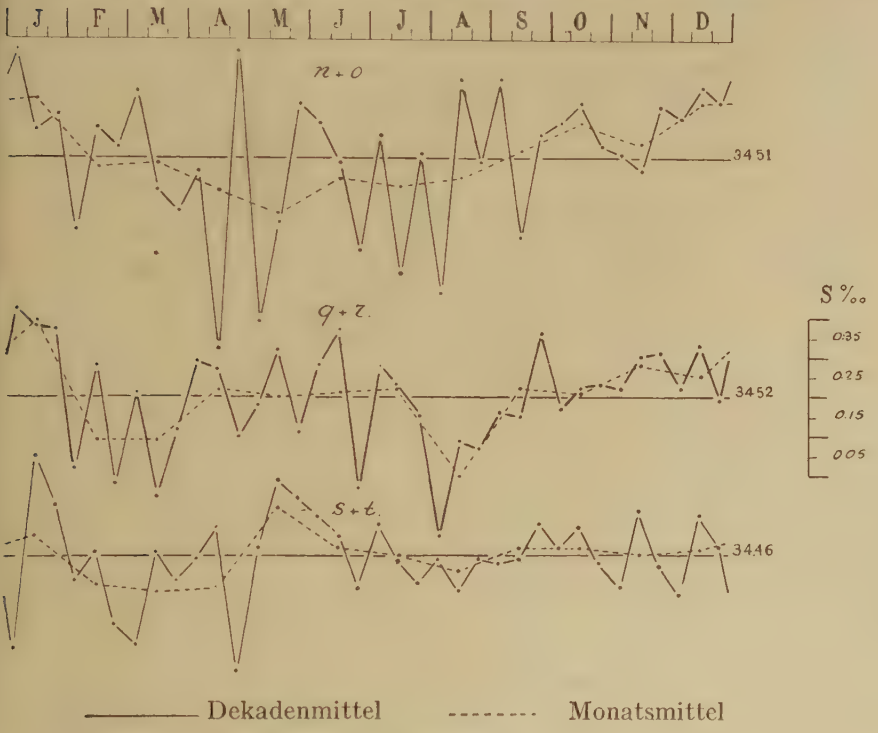

Fig. 4.

und 1912 beobachtet, ein Minimum in 1911. Feuerschiff Terschellingerbank zeigt schon in 1910 ein sekundäres Minimum, das für das Gebiet n—o das wichtigste wird, während auch hier noch in 1912 ein Maximum gefunden wird. In den Gebieten q—r und s—t tritt an die Stelle des Minimums in 1911 ein Maximum, was mit den Messungen auf dem Feuerschiff Smith's Knoll übereinstimmt. Von den beiden Minima ist nur das von 1910 noch zu bemerken.

Offenbar fliesst — wie oben schon bemerkt — auch ein Teil des der Küste von Norfolk entlang strömenden Wassers nach Osten, wodurch die Isohaline von 34.75 ‰ und sogar die von 34.50 ‰ durchbrochen wird. Der Verlauf der Isohalinen von Juli bis Oktober bestätigt diese

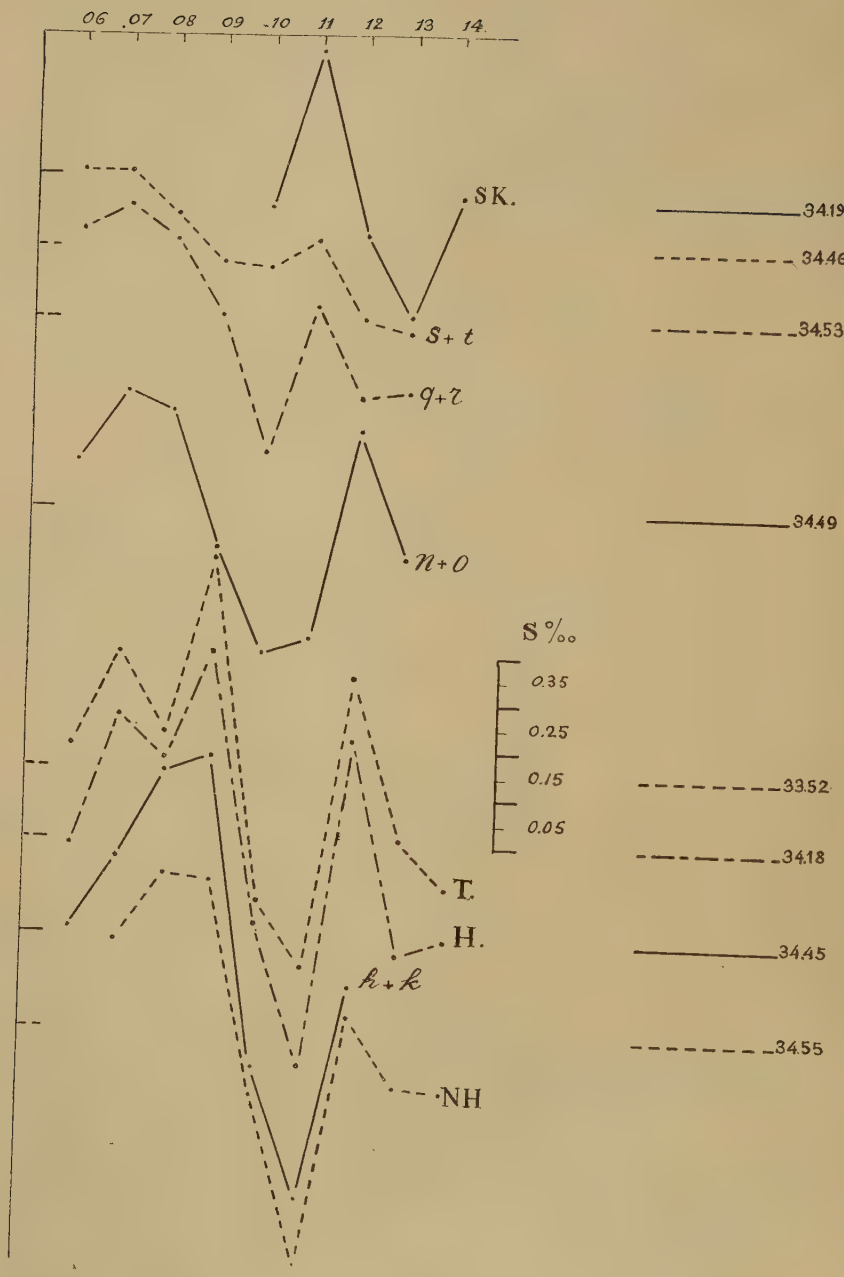
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Fig. 5.

Annahme. Vielleicht macht sich auch das holländische Flusswasser hier geltend, doch im Allgemeinen ist dieser Einfluss nur südlicher, vor den Rhein- und Maasmündungen, merkbar.

§ 6. Zusammenfassung. Das niederländische Beobachtungsmaterial, ergänzt durch das der englischen und belgischen Feuerschiffe und einige im Nordwesten zerstreut liegenden Salzgehaltmessungen setzte uns instand, die mittleren Monatsisohalinen zu konstruieren. Im Allgemeinen zeigen sie das bekannte Bild: Maximum Salzgehalt in der Mitte, im Osten ein Streifen salzarmes Küstenwasser, wechselnd in Breite, doch jedenfalls breiter als in der Nähe der englischen Küste. Die von uns berechneten Mittelwerte sind jedoch niedriger als von den bis jetzt veröffentlichten Karten, die sich auf den Terminbeobachtungen gründen, gezeigt wird.

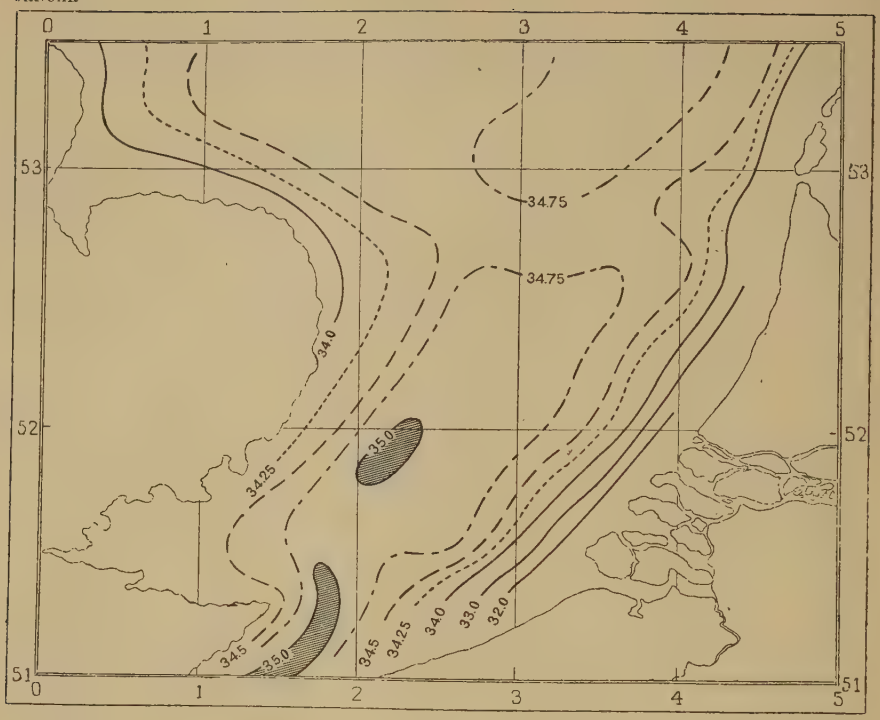
Nach Entfernung einiger weniger zuverlässig scheinenden Stationen der Dampferlinien scheinen uns die Messungen der Feuerschiffe und die grosse Anzahl Proben von den Dampfern eine Garantie für die Zuverlässigkeit der Monatskarten zu sein.

Hauptzweck der Bearbeitung waren diese Monatskarten; einige Bemerkungen betreffs des Verlaufs der Isohalinen in Bezug mit Wirbelbildung südwest der Doggerbank und vor der Mündung der Themse sind zugefügt. Weiter wird der Einfluss des holländischen Flusswassers und des lokalen Niederschlages auf den Oberflächensalzgehalt untersucht und die Standard-Abweichungen der Mittelwerte an der Station Noord Hinder für einige Dekaden berechnet. Die Berechnung einiger Korrelationskoeffizienten weist auf eine enge Beziehung zwischen den Salzgehaltsabweichungen der aufeinanderfolgenden Dekaden an derselben Station hin.

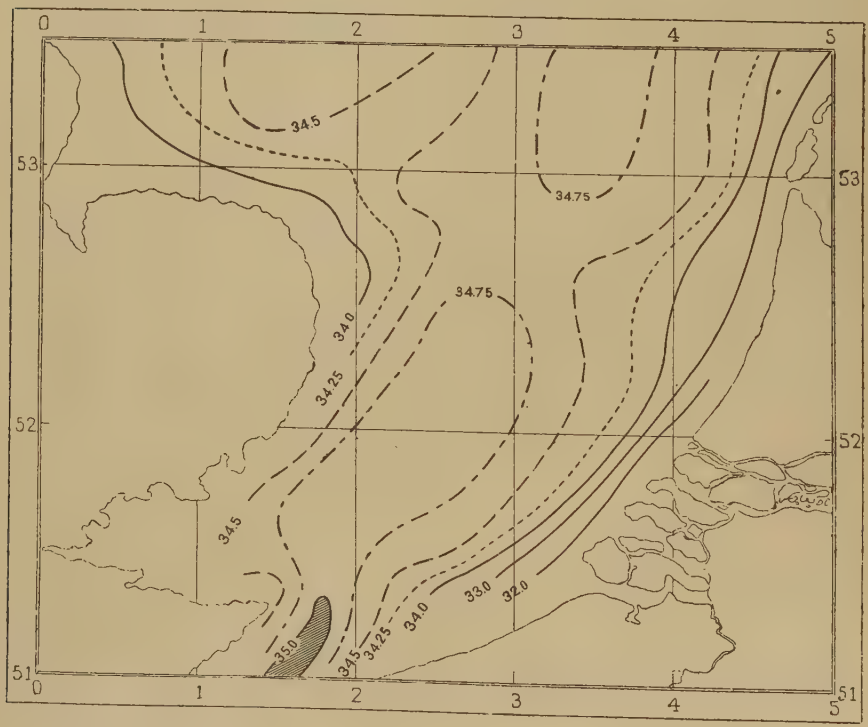
Die Bearbeitung der Daten erwies, dass sogar für dieses kleine Gebiet eine noch mehr systematische und vollständige Untersuchung erwünscht wäre, um die komplizierte und wahrscheinlich lokal immer wechselnde Wasserbewegung aus dem Verlauf der Isohalinen zu ergründen.

Die Monatskarten werden jedoch hoffentlich vorläufig den Biologen genügen für die Feststellung, inwiefern die aktuellen Salzgehaltverhältnisse an der Oberfläche von dem normalen Zustand abweichen.

JANUAR



FEBRUAR



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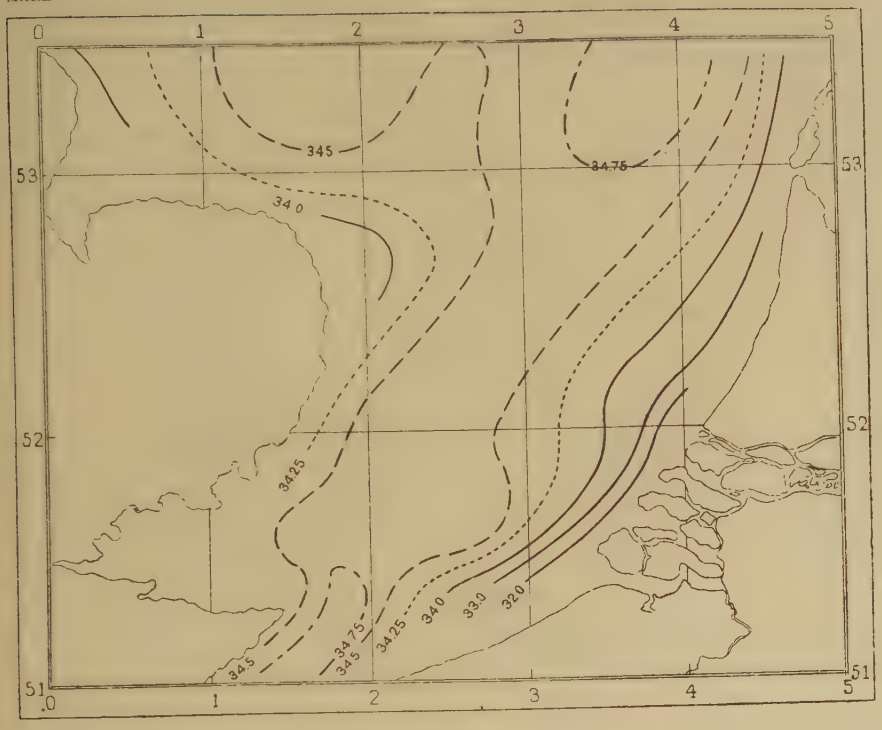
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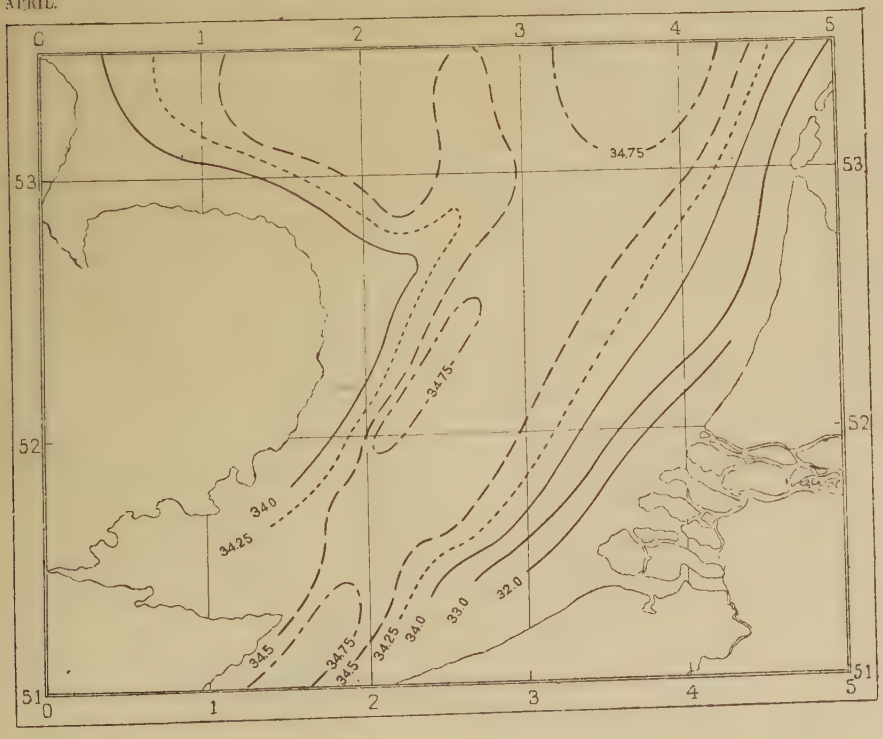
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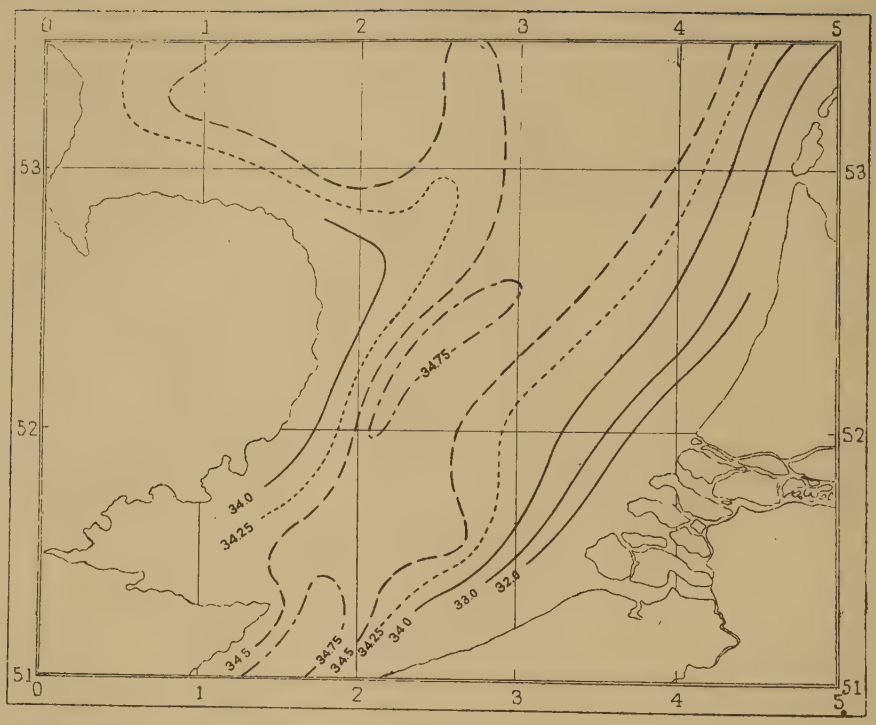
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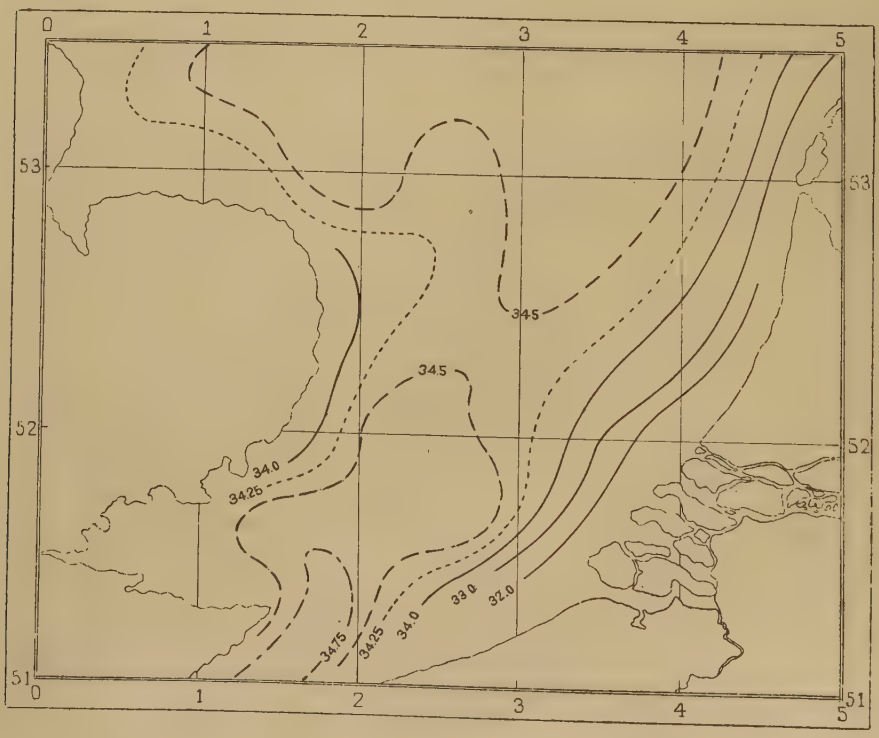
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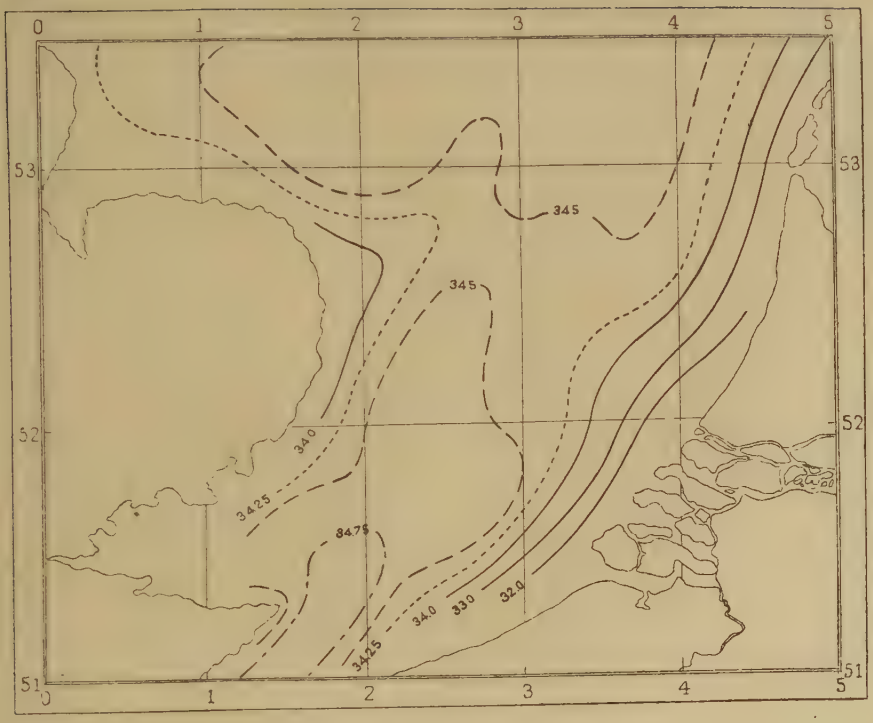
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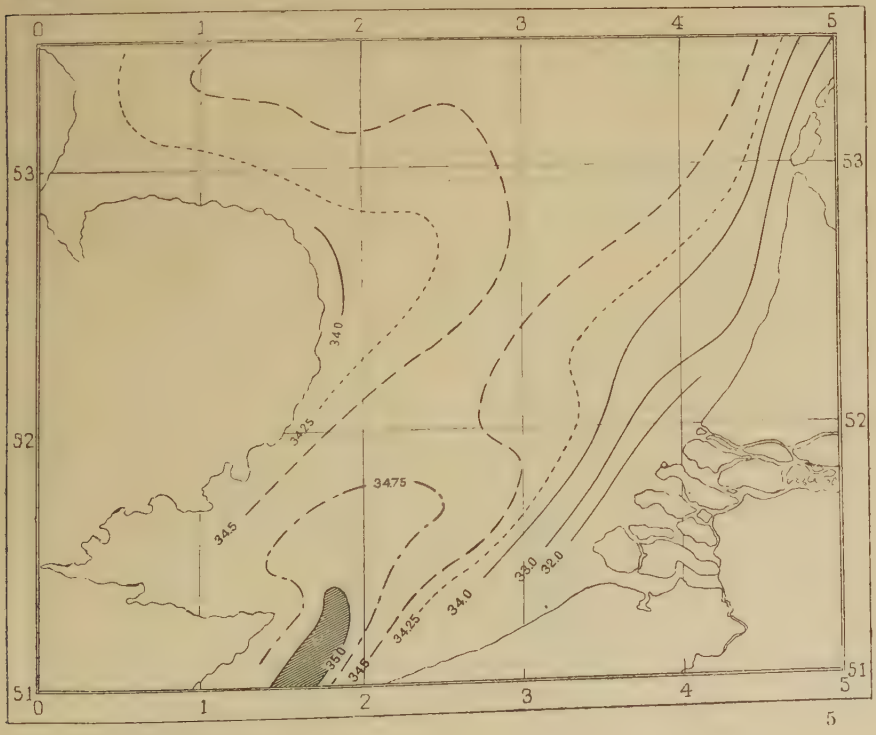
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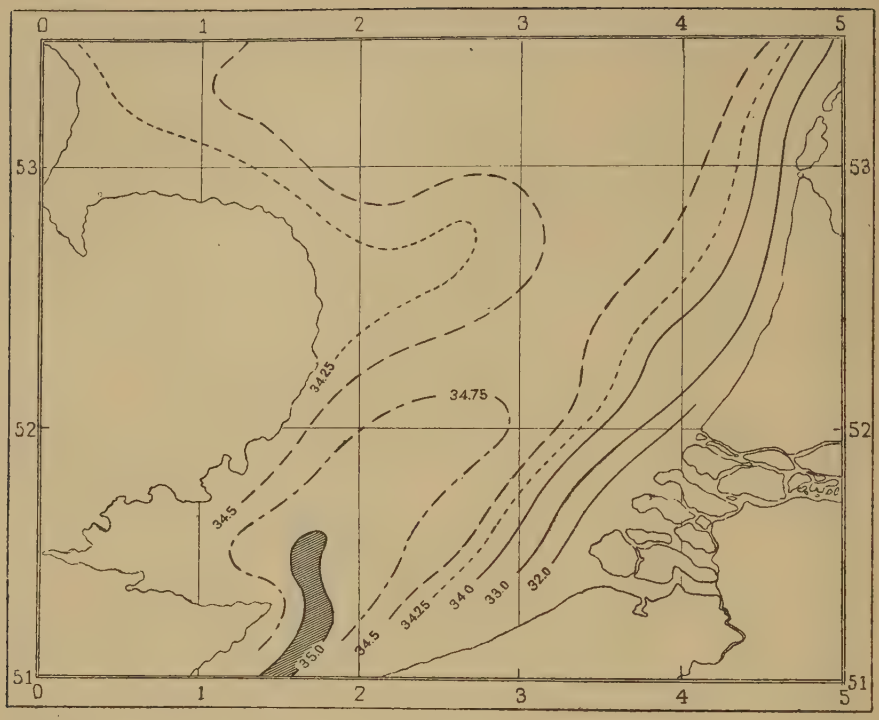
SEPTEMBER.



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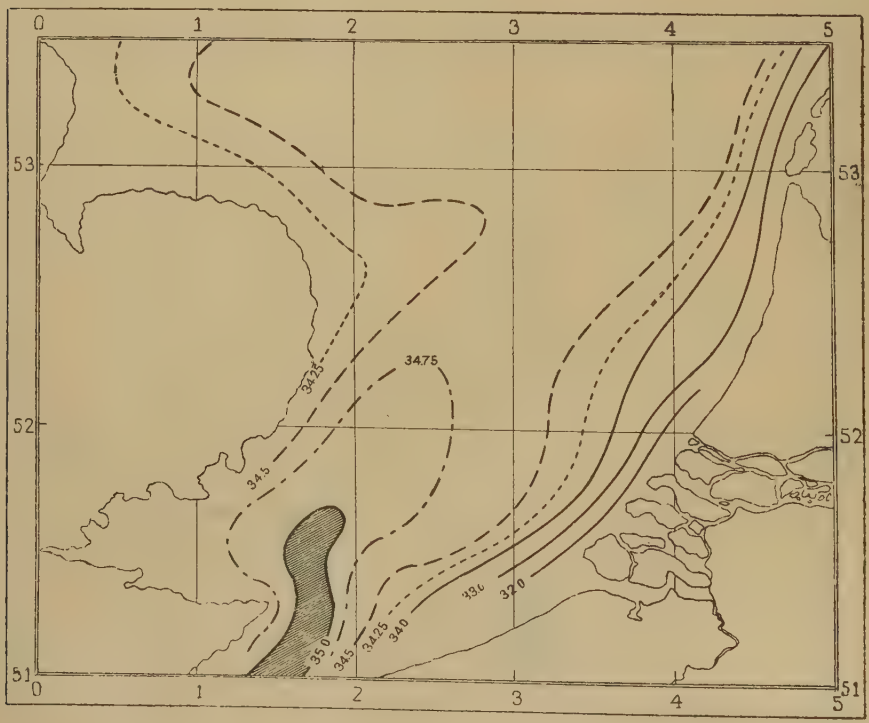

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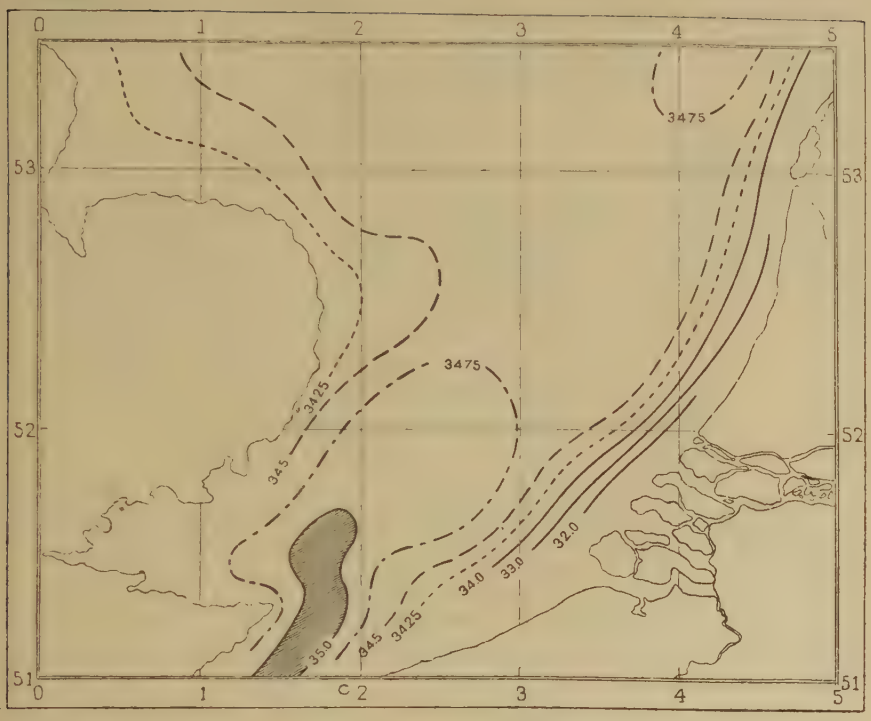

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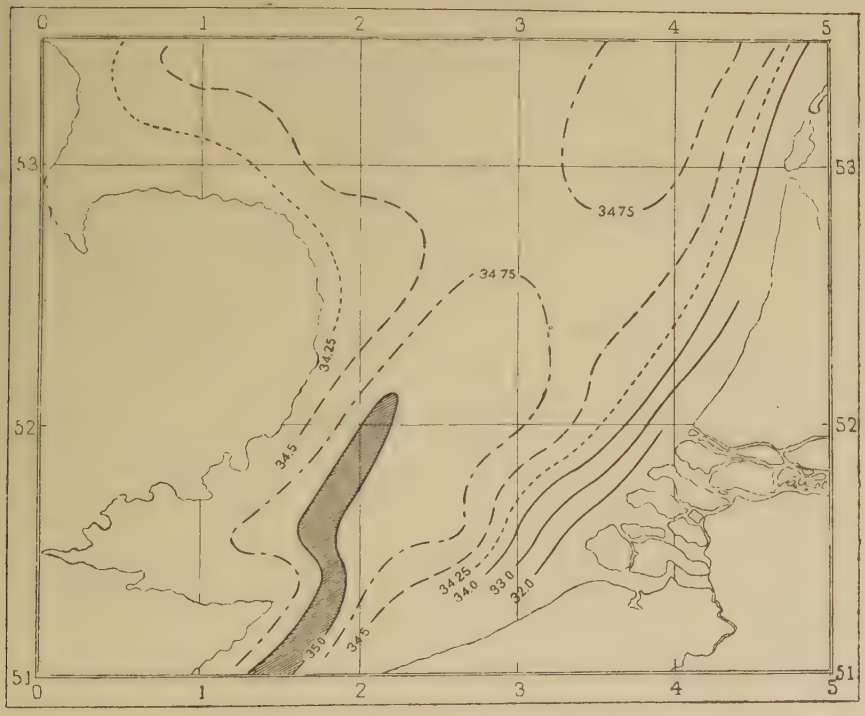


Die Durchlüftung des Atlantischen Ozeans.

(Vorläufige Mitteilung aus den Ergebnissen der Deutschen Atlantischen Expedition).

Von

H. Wattenberg.

(Mitgeteilt von der Notgemeinschaft der Deutschen Wissenschaft).

Die Kenntnis der Durchlüftung eines Meeres, d. h. die Versorgung seiner Tiefen mit Luft bezw. Sauerstoff, beansprucht besonders aus zwei Gründen Interesse: Erstens ist jedes höhere Leben an die Anwesenheit von Sauerstoff gebunden; ständige Zufuhr neuen Sauerstoffs ist daher Vorbedingung für die Erhaltung und Entwicklung der in den Tiefen der Meere lebenden Organismen. — Zweitens kann man aus der Intensität der Durchlüftung auf die Art der grossen Wasserbewegungen schliessen, die den Sauerstoff von der Oberfläche, an der er sich im Wasser auflöst, in die Tiefe zu den Verbrauchsorten befördern. Dadurch erfahren die Ergebnisse der Ozeanographen, die aus der Verteilung von Salzgehalt, Temperatur und Dichte diese Wasserbewegungen ebenfalls ermitteln, eine wertvolle Bestätigung und werden darüber hinaus in vieler Hinsicht ergänzt[1]).

Der Sauerstoffgehalt einer Wassermasse gibt unmittelbar ein Mass für ihren Durchlüftungszustand; den Mechanismus der Zufuhr des Sauerstoffs zu dieser Wassermasse, der uns für die Behandlung des zweiten Problems interessiert, kann man erst aus der vertikalen und horizontalen Verteilung des Sauerstoffs über ein möglichst grosses Gebiet erschliessen.

Ein für diese Zwecke geeignetes Beobachtungsmaterial wurde auf der Deutschen Atlantischen Expedition für den ganzen Südatlantischen und einen Teil des Nordatlantischen Ozeans gewonnen, wo auf 310 Stationen über 7000 Sauerstoffbestimmungen ausgeführt wurden. Mit

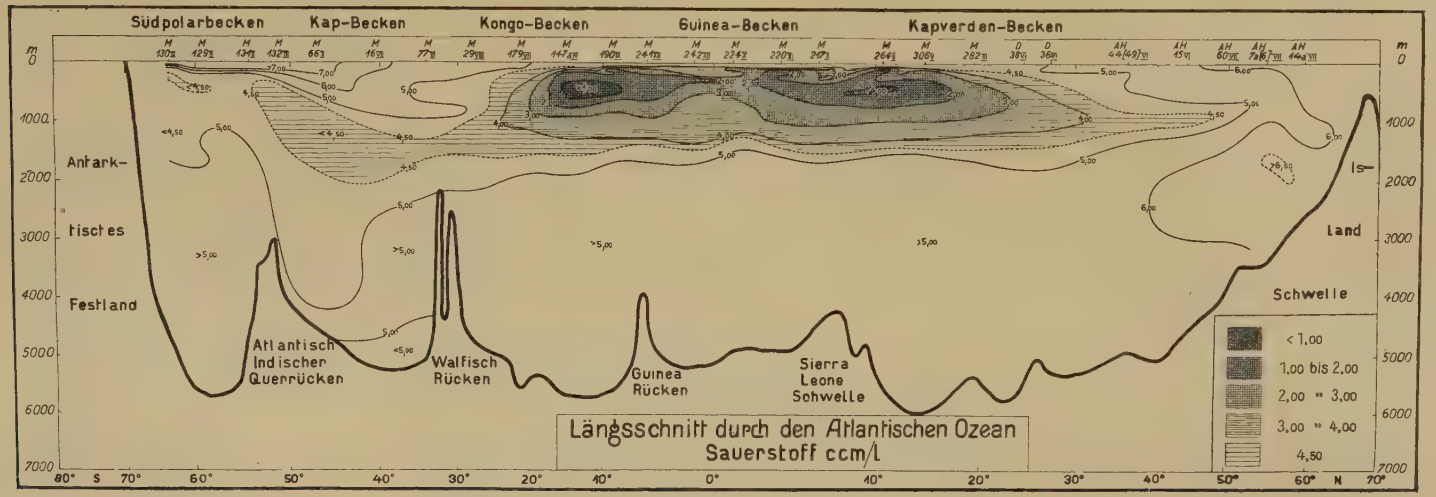
[1]) Br. Schulz (Naturwiss. 1924, S. 105) hat in ähnlicher Weise den Sauerstoffgehalt für die Diskussion der Durchlüftung von Nord- und Ostsee erfolgreich verwendet.

Fig. 1. Lage des Längsschnittes und des Querschnittes.

einem Teil dieses Materials wurde ein West-Ost-Schnitt und (unter Benutzung älterer Werte für den Nordatlantik) ein Nord-Süd-Schnitt konstruiert, die wie die zwei Achsen-Ebenen eines räumlichen Koordinatensystems die Hauptzüge der Sauerstoffverteilung im Atlantischen Ozean veranschaulichen sollen.

Die Anlage der Schnitte und das benutzte Material.

Schon bei der Planlegung der Expedition hatte Merz die besondere Bearbeitung einiger Längsschnitte in Aussicht genommen, in erster Linie solcher in den beiden Mulden westlich und östlich des Mittelatlantischen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Längsschnitt durch den Atlantischen Ozean
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Fig. 2.

Rückens. Von diesen Schnitten soll hier der Ost-Schnitt wiedergegeben werden, da dieser durch Benutzung einiger Stationen früherer Expeditionen bis zur Island-Schwelle nach Norden fortgesetzt werden konnte. Die Verteilung in west-östlicher Richtung wird durch einen Querschnitt

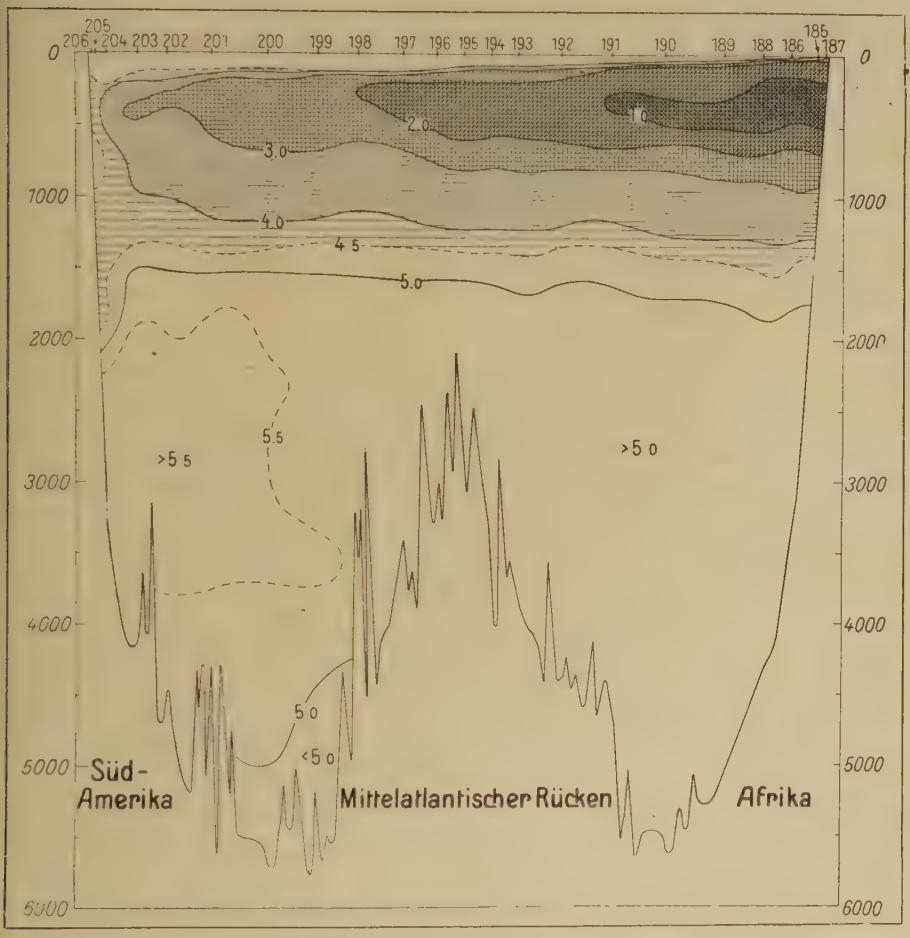

Fig. 3. Querschnitt durch den Atlantischen Ozean in 9° Süd. Sauerstoff ccm/l.

in 9° Süd dargestellt, der in einer besonders charakteristischen Zone verläuft. Für die Begründung der Lage des Längsschnittes gelten dieselben Gesichtspunkte, die G. Wüst[1]) für die ebenso verlaufenden Schnitte des Salzgehalts und der Temperatur anführt, d. h. im Wesentlichen morphologische. Der Längsschnitt ist deshalb auch nicht auf einen

[1]) G. Wüst, Der Ursprung der Atlantischen Tiefenwässer, Z. d. Ges. f. Erdk. zu Berlin, Jubiläumssonderband 1928. S. 506.

Mittelmeridian projiziert, sondern die einzelnen Stationen sind abstandsgetreu nach ihrer Entfernung in Seemeilen aufgetragen, da die Ausbreitung der Wassermassen, besonders in den tieferen Lagen, offenbar hauptsächlich durch die Morphologie bestimmt wird.

Alle Stationen des Querschnittes, sowie die südlich 20° Nord liegenden Stationen des Längsschnittes sind »Meteor«-Beobachtungen; nördlich davon sind 2 Stationen von W. Brennecke[1]) von der »Deutschland« und anschliessend 5 Stationen vom »Armauer Hansen« (in T. Gaarders[2]) Arbeit publiziert) benutzt worden. Sämtliche Sauerstoffbestimmungen sind nach der vorzüglichen Methode von Winkler ausgeführt worden und stellen demnach ein einheitliches und zuverlässiges Material dar. Die Konstruktion des Bodenreliefs beruht südlich 20° Nord auf der vorläufigen Tiefenkarte der »Meteor«-Expedition[3]), nördlich davon auf der Darstellung von M. Groll[4]).

Die Verteilung des Sauerstoffs und ihre Ursachen.

A. Die meridionale Verteilung. In der meridionalen Verteilung des Sauerstoffs, wie sie durch den Nord-Süd-Schnitt wiedergegeben ist, können wir drei gut charakterisierte Schichten unterscheiden, die ungefähr mit den von Defant[5]) in Analogie zur Atmosphäre eingeführten Begriffen: Störungszone, Troposphäre und Stratosphäre zusammenfallen:

1) Eine sauerstoffreiche Oberflächenschicht, d. i. die durch Austausch mit der Atmosphäre gut durchlüftete Störungszone,
2) eine sauerstoffarme Zwischenschicht, deren Sauerstoffgehalt oft bis unter 1 ccm/l sinkt, die Troposphäre, in der der Sauerstoffgehalt nach unten zu zunimmt, bis sie übergeht in die
3) sauerstoffreiche Stratosphärenschicht, deren Wasser mit einem Gehalt von 5—6 ccm/l die grossen Tiefen unter etwa 1500 m ziemlich gleichmässig ausfüllt.

Die Gründe für die Ausbildung der obersten der drei unterschiedenen Schichten sind ohne weiteres einleuchtend. Konvektion und Austausch

[1]) W. Brennecke, Die ozeanographischen Arbeiten der Deutschen Antarktischen Expedition 1911—1912. Archiv d. Seewarte, XXXIX, No. 1. Hamburg 1921.

[2]) T. Gaarder, Die Sauerstoffverhältnisse im östlichen Teil des Nordatlantischen Ozeans. Geophysiske Publikasjoner Vol. IV, No. 3. Oslo 1927.

[3]) A. Defant, Bericht über die Ergebnisse der Meteor-Expedition. Z. f. Geophysik 3, S. 340—350. Braunschweig 1927.

[4]) M. Groll, Tiefenkarten der Ozeane. Veröff. d. Inst. f. Meereskunde, N. F., Reihe A, Heft 2. Berlin 1912.

[5]) A. Defant, Die systematische Erforschung des Weltmeeres, Z. d. Ges. f. Erdkunde zu Berlin, Jubiläumssonderband 1928, S. 459.

bewirken eine gute Durchlüftung bis in wechselnde, jeweils von den klimatischen und meteorologischen Faktoren abhängige Tiefen. In den hohen Breiten mit ihren starken jahreszeitlichen Temperaturschwankungen reicht die Mischung ziemlich tief, in den Tropen und Subtropen dagegen, wo die starke Erwärmung und das gleichmässige Klima eine ausgesprochene Dichteschichtung hervorrufen, hat die gut durchlüftete Schicht nur eine Mächtigkeit von etwa 50 - 150 m. Wie vollständig eine

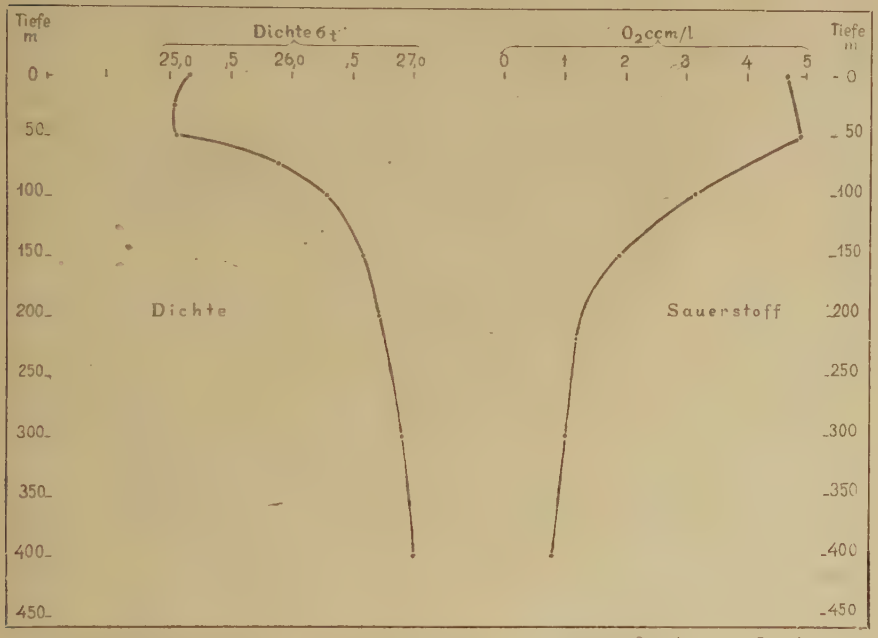

Fig. 4. Vertikale Verteilung von Dichte und Sauerstoff in 15°2,6′ Süd, 0°6,7′ West.

starke Dichteschichtung, eine Dichtesprungschicht, das Weiterreichen des Austausches nach unten verhindert, zeigt ein Vergleich der Vertikalverteilung von Dichte und Sauerstoff, wie er in Figur 4 für eine tropische Station in 15°2,6′ Süd, 0°6,7′ West gegeben ist.

Die unter der Diskontinuitätsfläche gelegene Schicht erhält also auf dem nächsten Wege zur Atmosphäre, von oben her, fast keine Sauerstoffzufuhr, sondern muss ihn durch horizontalen Einschub beziehen, wenn sie nicht vollständig daran verarmen soll. Dieser seitliche Einschub wird, wie die Schnitte von G. Wüst[1]) zeigen, in den Schichten zwischen ca. 400 und 1100 Meter durch den subantarktischen Zwischenstrom und in den tieferen Schichten vor allem durch den Nordatlantischen Tiefen- und Bodenstrom geleistet.

[1]) l. c.

Es ist danach nicht einzusehen, weshalb die höheren Schichten (etwa zwischen 200 und 1400 m) so auffallend wenig Sauerstoff enthalten, zumal man annehmen sollte, dass die Strömungen der geringeren Tiefen wegen ihrer grösseren Geschwindigkeit den Sauerstoff schneller ergänzen würden als die Strömungen der grossen Tiefen. Nach der Herkunft der Tiefenströme sollte man ebenfalls eher erwarten, dass die geringeren Tiefen besser durchlüftet wären, da der subantarktische Zwischenstrom seine Wassermassen aus besonders sauerstoffreichen Gebieten bezieht. Das Gegenteil ist der Fall. Der subantarktische Zwischenstrom durchdringt gerade den Kern des grossen tropisch-subtropischen Minimumgebietes. Es ist daher zu verstehen, dass man diese Diskrepanz geradezu als Gegenbeweis gegen das Vorhandensein eines solchen Horizontalstromes angesehen hat. Das ist natürlich kein befriedigender Ausweg und wir müssen uns nach anderen Ursachen für diese merkwürdige Vertikalverteilung des Sauerstoffs umsehen, besonders nach solchen, die den Sauerstoff-Verbrauch innerhalb jeder Wassermasse selbst beeinflussen.

Als Faktoren, die die Geschwindigkeit der Sauerstoffzehrung bestimmen und einer quantitativen Beurteilung zugänglich sind, kommen vor allem in Frage:

Die vertikale Verteilung der Temperatur, die, von oben nach unten zu stark abnehmend, in geringeren Tiefen mit wärmerem Wasser die chemischen Vorgänge mit höherer Geschwindigkeit verlaufen lässt als in grösseren Tiefen mit kälterem Wasser, und die vertikale Verteilung der organischen Substanz, die in den grösseren Meerestieren, Planktonorganismen und Bakterien verkörpert ist und der Oxydation zugeführt wird.

Zahlenmässig bekannt ist die Verteilung der Temperatur und des Nannoplanktons. Dieses kann man in erster Annäherung als proportional dem Gesamtplankton annehmen, da sowohl die grösseren Meeresorganismen in ihrer Menge der Konzentration an Zwergplankton folgen, als auch die von den Planktonleichen lebenden Bakterien sich dort einstellen, bezw. schnell vermehren werden, wo viele Organismen leben und sterben.

Beide Faktoren, Temperatur und Planktongehalt, verstärken sich also gegenseitig in ihrem Einfluss auf die Verteilung des Sauerstoffs und zwar in der Richtung auf einen Zustand, der dem in Wirklichkeit vorhandenen ähnlich ist. Grössenordnungsgemäss kann man diese Wirkungen oder vielmehr die Unterschiede dieser Wirkungen in den verschiedenen Schichten auch quantitativ berechnen und mit den gefundenen Unterschieden im Sauerstoffdefizit vergleichen. Das Ergebnis einer solchen Rechnung mag hier mit allem Vorbehalt, der durch die ver-

schiedenen vereinfachenden Annahmen bedingt ist, wiedergegeben werden.

Um keine Störung durch Sauerstoff-zuführende Assimilation und Konvektion zu haben, wird die oberste Schicht, die »Störungszone« aus der Betrachtung fortgelassen. Vergleicht man nun die Abnahme des Sauerstoffgehalts einer Wassermasse innerhalb einer horizontalen Strömung für eine gewisse Wegstrecke[1]) mit der in derselben Schicht vorhandenen Planktonmenge und der dort herrschenden Temperatur, so findet man, dass die Sauerstoffabnahme annähernd proportional der Planktonmenge und der von der Temperatur abhängigen Reaktionsgeschwindigkeit[2]) ist. Da nun, wie gesagt, Temperatur und Planktongehalt mit der Tiefe stark abnehmen, wird — gleichmässige horizontale Zufuhr von Sauerstoff auf Grund der Salzgehaltsverteilung vorausgesetzt — in gleicher Weise der Sauerstoffgehalt mit der Tiefe stark zunehmen. Es soll einstweilen darauf verzichtet werden, Zahlen für diese Beziehungen anzugeben, ehe nicht die ausführliche Bearbeitung über ein grösseres Gebiet vorliegt.

Es scheint demnach, dass die Vertikalverteilung des Planktons und der Temperatur die Hauptursache für die Entstehung des Minimums und allgemein für die Vertikalverteilung des Sauerstoffs in den niederen Breiten unterhalb der Dichtesprungschicht vorstellen. Die aus der Salzgehaltsverteilung gezogenen Schlüsse über die Tiefenströmungen stehen demnach in keinem Gegensatz mehr zu der Verteilung des Sauerstoffs und es ist nicht nötig, besonders stagnierende Wassermassen in den sauerstoffarmen Schichten anzunehmen, wie es gelegentlich zur Stützung der älteren Anschauungen über die Tiefenzirkulation geschah, welche aufsteigendes Wasser in den Äquatorialzonen in grösserem Umfange annahm.

Dass der grösste Sauerstoffmangel nicht unmittelbar unter der Sprungschicht, sondern ca. 300 m tiefer liegt, ist darauf zurückzuführen, dass die Sprungschicht natürlich nicht einen Austausch absolut unterbindet, sondern in immerhin merklichem Masse Sauerstoff von oben hindurchtreten lässt und dadurch den Kern des Minimums in grössere Tiefen drückt. Ebenso wird vielleicht die eigenartige Unterbrechung des Kerns

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[1]) Man kann nicht, wie es oft geschieht, ohne weiteres die Sättigungsprozente des Sauerstoffs als Mass für den Sauerstoffverbrauch ansehen, da zwar der Salzgehalt, aber keineswegs die Temperatur auf grössere Strecken auch nur annähernd gleich bleibt.

[2]) Diese wächst nach den vorliegenden Arbeiten etwa um 10 % für 1° C. Temperatursteigerung. (Vergleiche H. W. Harvey, Biological Chemistry and Physics of Sea Water, Cambridge 1928, S. 17 ff.)

am Äquator durch einen stärkeren Austausch infolge der hier schwächer ausgebildeten Sprungschicht hervorgerufen; doch scheint auch Sauerstoff aus dem Bereich des Nordatlantischen Tiefenstroms das Minimumgebiet von unten her etwas einzuschnüren.

Wir haben vorher, in Übereinstimmung mit den Ergebnissen der Ozeanographie, festgestellt, dass die unter der Dichtesprungschicht liegenden Schichten ihren Sauerstoffgehalt zur Hauptsache durch seitlichen Einschub erhalten. Es soll jetzt näher untersucht werden, aus welchen Gebieten diese Schichten letzten Endes ihren Sauerstoffgehalt beziehen, wo also die »Sauerstoffventile« (Gaarder) für die Tiefsee liegen.

So, wie sich die Verhältnisse in dem vorliegenden Längsschnitt wiederspiegeln, ist es nun merkwürdigerweise unmöglich, einen Zusammenhang der sauerstoffreichen Tiefenschichten mit der Meeresoberfläche zu konstruieren, von der doch allein die Zufuhr des Sauerstoffes ausgehen kann. Doch kann man feststellen, wo zeitweilig ein Absinken am wahrscheinlichsten stattfindet, da dort in vertikaler Richtung die geringsten Unterschiede im Sauerstoffgehalt vorhanden sein werden. Das ist in den subpolaren Gebieten der Fall. Aber auch hier ist nach dem Schnitt kein auch nur annähernd gleicher oder gleichmässig abnehmender Gehalt von der Oberfläche zur Tiefe zu finden, wie es der Fall sein müsste, wenn dauernd ein vertikaler Austausch oder ein Absinken vor sich ginge. Zwar sind an der Oberfläche in diesen höheren Breiten die Sauerstoffkonzentrationen ebenso gross oder grösser als ebendort in den grossen Tiefen, und in diesen Breiten könnte sich also das Tiefenwasser bilden, aber zur Zeit der Aufnahme unseres Längsschnittes bildet sich das Tiefenwasser nicht, wie die sauerstoffärmere Zwischenschicht beweist. Nun ist aber zu berücksichtigen, dass sämtliche Stationen der höheren Breiten im Sommer aufgenommen sind, und in dieser Jahreszeit grösster Erwärmung des Oberflächenwassers und der deshalb stabilen Schichtung sind die Bedingungen für ein Absinken und eine Konvektion am ungünstigsten. Die in dem Schnitt dargestellte Sauerstoffverteilung beweist also nichts dagegen, dass, wie es Nansen wahrscheinlich gemacht hat, in der kalten Jahreszeit die Bildung des Tiefenwassers vor sich geht. Die Rücksicht auf möglichst vorteilhafte Arbeitsbedingungen hat uns bisher leider keine Winterstationen aus diesen Zonen gewinnen lassen, durch die wir experimentelles Beobachtungsmaterial während dieses Vorganges bekommen hätten; diese müssten nämlich das Verschwinden des intermediären Sauerstoffminimums zeigen.

Das in der kalten Jahreszeit abgesunkene Wasser breitet sich in der

Tiefe gemäss seiner Dichte flächenhaft aus. Sein Sauerstoffgehalt nimmt vom Entstehungsgebiet in der Fortbewegungsrichtung infolge Verbrauchs zur Oxydation organischer Substanz allmählich ab. Diese Abnahme ist jedoch nicht kontinuierlich, sondern zeigt Unstetigkeiten, besonders im Gebiet des Nordatlantischen Tiefenstroms, die allerdings in dem hier wiedergegebenen Längsschnitt, in dem die Isolinien von 0,5 zu 0,5 ccm/l gezogen sind, nicht zum Ausdruck kommen. Diese Unstetigkeiten können sehr wohl durch das schubweise Vordringen des Tiefenwassers, das durch das intermittierende Absinken bewirkt wird, hervorgerufen sein.

B. Die zonale Verteilung des Sauerstoffs (vergl. Fig. 3). Haben wir bisher die Sauerstoffverteilung im Atlantischen Ozean vorwiegend projiziert auf eine nord-südlich gelegene Ebene betrachtet, so wollen wir jetzt auf die Verteilung des Sauerstoffs in west-östlicher Richtung und ihre Ursachen eingehen.

Obwohl in dieser Richtung, wie zu erwarten, die Unterschiede geringer sind, so gibt es doch einige Faktoren, deren Wirkung auch oder gerade in den Schnitten parallel den Breitenkreisen zum Ausdruck kommt. Das sind die ablenkende Kraft der Erdrotation, die morphologischen Verschiedenheiten der West- und der Osthälfte des Ozeans, die Unterschiede in der Verteilung des Planktons und schliesslich auch die geographische Lage der Entstehungsgebiete der Tiefengewässer. Wir wollen nun untersuchen, in welcher Weise die einzelnen Faktoren den Sauerstoffgehalt beeinflussen, ob sie etwa teilweise oder ganz in dem gleichen Sinne wirken und sich so gegenseitig verstärken.

Die Erdrotation wirkt direkt auf die Meridionalströmungen in der Weise, dass äquatorwärts strömende Wassermassen nach Westen, polwärts strömende nach Osten abgelenkt werden. Es erscheint hierdurch erklärlich, dass das auf der Nordhalbkugel absinkende und sich nach Süden fortbewegende Tiefenwasser auf die amerikanische Küste zu gedrängt wird, an der es sich bis weit über den Äquator hinaus hält; wenn später im Süden die ablenkende Kraft wieder gross geworden ist, wird dieses Wasser an einem Übertreten ins Ostbecken durch die Mittelatlantische Schwelle verhindert. Die Hauptmengen des sauerstoffreichen nordatlantischen Wassers erfüllen also die Tiefen der westlichen Ozeanhälfte. Auch die starke Ablenkung des Subantarktischen Zwischenstromes nach Westen ist von merkbarem Einfluss auf die zonale Verteilung des Sauerstoffs in den geringeren Tiefen, in denen dieser Strom fliesst.

Die morphologischen Verhältnisse, d. h. speziell die verschiedene Bodengestaltung von West- und Ost-Becken, unterstützen in den grös-

seren Tiefen die Wirkungen der Erdrotation. G. Wüst[1]) hat bei der Diskussion der Verteilung des Salzgehalts ausführlich die Bedeutung der Morphologie für die Ausbreitung des Tiefenwassers begründet, sodass hier nur kurz zusammengefasst werden braucht: Während das Westbecken den Tiefenströmen freien Durchzug gestattet, stellen sich ihnen im Ostbecken mehrere quergestellte Rücken in den Weg, die einzelne Mulden abriegeln und erst oberhalb verhältnismässig geringer Tiefen Durchlässe besitzen. Mit der Ausbreitung der Tiefenströme als Zufuhrquellen des Sauerstoffs ist aber der Zustand der Durchlüftung in den grossen Tiefen unmittelbar verknüpft.

Noch ehe Erdrotation und morphologische Verhältnisse ihren Einfluss ausüben können, macht sich schon eine Bevorzugung des westlichen Teils des Ozeans für die Durchlüftung bemerkbar, der durch die geographische Lage der Entstehungsgebiete des Tiefenwassers bedingt ist. Im Norden haben wir nach G. Wüst[1]) als Hauptabsinkgebiete anzusehen die Ostgrenze des Ostgrönlandstromes und die Südgrenze des Labradorstromes, d. h. die grossen Stromkonvergenzen der kalten Polarwässer, die ozeanische Polarfront Defants[2]). Wie aus der Karte der Oberflächen-Strömungen Hans H. F. Meyers hervorgeht, in die Wüst[1]) diese Gebiete eingetragen hat, wird das nordatlantische Tiefen- und Bodenwasser, das ja als Hauptbestandteil die grossen Tiefen des Ozeans ausfüllt, im westlichen Atlantischen Ozean oder vielmehr, was hier wesentlich ist, westlich der Mittelatlantischen Schwelle gebildet. Im Süden ist eine gleichsinnige Unsymmetrie weniger gut ausgeprägt, aber die hier entstehenden Tiefenwässer treten ja auch gegenüber den Nordatlantischen weit in ihrer Bedeutung für die Durchlüftung zurück.

Abgesehen von diesen mehr von aussen her wirkenden Faktoren kann man auch in den Eigenschaften jeder Wassermasse selbst die Ursache für die mehr oder weniger schnelle Zehrung des Sauerstoffes suchen, wie wir es bei der vertikalen Verteilung des Sauerstoffs gemacht haben, indem wir den Einfluss von Temperatur und Planktongehalt berücksichtigten. Die Temperatur ist nun zwar in der gleichen Tiefe im Westen und Osten nicht wesentlich verschieden, aber in der Planktonverteilung finden wir so erhebliche Differenzen, dass man einen Einfluss auf die Sauerstoffverteilung erwarten sollte. Wie Hentschel[3]) gezeigt hat, ist das Plankton im Osten ausserordentlich viel reicher als im Westen, und dieser Unterschied erstreckt sich bis in grosse Tiefen.

[1]) l. c.

[2]) A. Defant, Die systematische Erforschung des Weltmeeres, Z. d. Ges. f. Erdk. Jubiläumsband 1928.

[3]) E. Hentschel, Internat. Revue f. Hydrobiol. u. Hydrogr. Bd. 21. S. 1—16. (1928).

Unterhalb der Assimilationsschicht wird also das Wasser durch Atmung der lebenden sowie bakterielle Zersetzung der abgestorbenen Planktonorganismen im Osten schneller an Sauerstoff verarmen als im Westen.

Zu welchem Prozentsatz jeder dieser vier gleichsinnig wirkenden Faktoren die Verteilung des Sauerstoffs in zonaler Richtung bestimmt, ist bei unseren heutigen Kenntnissen nicht zu entscheiden. Es ist jedoch möglich, dass schon die weitere Bearbeitung des Meteormaterials uns in manchen Punkten etwas genauere Angaben zu machen gestattet.

Summary.

The great depths of the Atlantic Ocean (below ca. 1500 m.) are well aerated, the western part better than the eastern part. Passing from the depths upwards towards the surface, the oxygen content reaches a minimum just below the discontinuity layer. The lowest values are found in the eastern part of the tropical Ocean where the content falls below 0,5 ccm./l. Above the discontinuity layer mixing by convection brings about very good aeration.

The discontinuity layer, especially in low latitudes, hinders the air supply from the surface passing into the deep layers, since it almost stops mixing by convection. These deep layers get their oxygen almost entirely by means of horizontal currents.

The well marked minimum may be due to the greater consumption of oxygen owing to the greater number of plankton organisms and the high temperature in the upper layers; both decrease with depth in about the same proportion as the oxygen content increases. The tropical—subtropical minimum in oxygen is no longer in contradiction with our modern ideas of the deep water movements deduced from the distribution of the salinity, as it seemed to be before this explanation was advanced.

Water, rich in oxygen, which fills the depths of the Atlantic has its origin in the northern and southern polar and subpolar sinking centres. Sinking occurs especially in winter when the intermediate layer, having minimum dissolved oxygen, disappears in these areas.

Deep water in the eastern part of the ocean contains less dissolved oxygen than the deep water of the western part. This is due to the greater plankton population in the eastern part, to the influence of the geographic situation of the sinking centres, to the influence of the earth's rotation and of the shape of the sea bottom. These latter three factors all cause a better development of the deep sea currents rich in oxygen in the western basin of the Atlantic Ocean, while greater oxygen consumption by the richer plankton in the deep water of the eastern basin lowers its oxygen content more than in the western basin.

Hydrodynamics of the Waters South East of Ireland.

By

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When water in the oceans moves horizontally as a current, the moving particles are subjected to a force acting at right angles to their direction of motion whatever the direction in which they are travelling. This deflective force, due to the earth's rotation, is directly proportional to the horizontal velocity of the particles. It is at a maximum near the poles, falling to zero at the equator. In the northern hemisphere the force tends to deflect the moving water to the right and in the southern hemisphere to the left. The magnitude of the force acting upon unit mass, at right angles to its direction of motion, is given in the well known equation

$$F = 2\omega v \sin \text{ latitude} \qquad (1)$$

where ω is the angular velocity of the earth's rotation and v is the velocity of the particles.

The magnitude of the force is independent of the direction in which the water moves.

As a result of this force, water moving in a current piles up on the right hand side of the current in the northern hemisphere. There is an actual deformation of the surface, but the height to which the water is piled up is always very small.

When, as is frequently the case, the upper lighter layers move as a current, slipping over the denser water below, not only does the surface rise slightly on the right hand side of the current but also the upper lighter layer becomes considerably deeper on the right hand side and thinner on the left hand side of the current. The thickening of the moving lighter strata on the right hand side of the current in the northern hemis-

phere may be illustrated in the following manner. If a layer of oil lies on a bottom stratum of water in a hypothetical tank which is indefinitely long, the boundary layer will be horizontal. If the oil moves forward while the water remains at rest, then the moving oil will be forced to the right and the oil layer become thicker on the right hand side than on the left hand side of the current; the separating line will lie obliquely. The obliquity of the separating line depends upon (i) the magnitude of deflective force due to the earth's rotation, this varies with the sine of the latitude. (ii) The difference between the density of the oil and of the water. (iii) The velocity with which the oil is moving over the surface of the water. Once the velocity has become steady, equilibrium is soon established with the separating surface between the oil and water layer lying at an angle to the horizontal.

When in the sea the upper lighter strata are moving in the same direction and at the same speed as the lower denser strata, or when both are stationary, then the surfaces of equal pressure will all lie parallel with the surface of the sea. When one stratum starts to move over the stratum below and attains a steady velocity, the surfaces of equal pressure become deformed and soon take up a condition of equilibrium. If the current ceases, the surfaces quickly become horizontal again.

It is the current which maintains this deformation of the surfaces of equal pressure from the horizontal. At the outset it may be caused by the current as in the cases considered, or the primary cause may be less dense water running in slowly from land drainage or melting ice and giving rise to a current which, by thickening the lighter stratum on one side, hinders the lighter water from running out to sea and a general levelling up from taking place. In either case the surfaces of equal pressure are displaced from the horizontal and maintained in this state while the current continues. In consequence an internal field of force exists within the water.

This internal field of force can be measured and from the measurements the current maintaining it can be calculated.

If the weight of water above some arbitrary level is plotted for a number of positions, where hydrographic observations have been made within a few days of each other, it is possible to draw lines of equal hydrostatic pressure at that level, similar to the isobars of a meteorological diagram (Figure 3). These lines indicate the direction of flow of the water at the surface relative to the flow at the chosen level. Where the lines of equal hydrostatic pressure lie closest together the forces giving rise to a difference in velocity of the water at the surface and at the chosen level will be greatest.

Computation of Velocity.

The weights of vertical columns of water having 1 square cm. cross section from the surface to the chosen depth can be calculated for each hydrographic station as in the following example.

Station 2110.

Depth meters	Depth of statum cms	Temp. °C.	Salinity ‰	Specific gravity at t°	Mean specific gravity of stratum	Weight in gms of column of unit cross section through stratum
0		15.24	35.30	1.02616		
	1000				1.02622	1026.22
10		14.77	35.29	1.02627		
	1000				1.02634	1026.34
20		14.10	35.28	1.02641		
	2000				1.026815	2053.63
40		10.11	35.35	1.02722		
	2000				1.027215	2054.43
60		10.11	35.34	1.02721		

Total weight in gms. of column 1 cm. square in section extending from surface to 60 meters ..... 6160.6 gms.

The density of sea water is calculated from its salinity and temperature by means of KNUDSEN's Hydrographical Tables. This process is made more rapid and less tedious by using a nomograph which can be made as follows:—

The density (or σ_t) at the highest temperature usually met with is found from the tables for waters differing in salinity by 0.5 ‰, and having a range of 2 or 3 ‰. For the area here considered a temperature of 17°

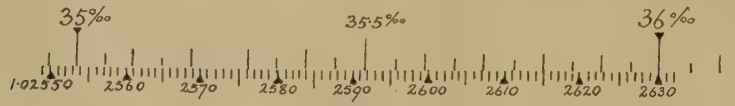

Fig. 1.

and salinities between 34 ‰ and 36 ‰ were chosen. A long strip of squared paper is pasted to a board and a scale of densities made, each division corresponding to .00001 and being about 3 mm long. The salinities are marked against the corresponding densities (Fig. 1) and the salinity scale further subdivided.

Next the increase in density for successive falls of 1° C. are obtained, from the data given in KNUDSEN's tables, for waters of various salinities, 34 ‰, 35 ‰ and 36 ‰ in this instance. They are plotted on squared

paper and "faired" curves drawn. A strip of thin celluloid is then ruled with three lines (labelled 34 $^0/_{00}$, 35 $^0/_{00}$ and 36 $^0/_{00}$ respectively) converging to a point on the left, labelled 17° (Fig. 2). Along the three lines scales are divided, each division shewing the increase in density for a fall of 0.1° C. in the same units of length as the density scale on the paper strip. If this celluloid strip is then laid on the paper strip with the 17° C. point

Fig. 2.

upon a salinity division, the density corresponding to this salinity and to any temperature below 17° can be read off on the paper scale.

Mr. Oscar Sund, Fjeldlien 1, Bergen, has designed and made arrangements for the supply of large nomographs, by which the density corrected for compression may also be calculated.

In this calculation no account is taken of compression. The effect of compression of the water is so nearly the same on columns extending to the same depth, that making allowances for it does not materially effect the difference in calculated weights of such columns, and it is upon these differences in weight that the computation of velocity depends. As an instance of neglecting the effect of compression we may take the data for two hydrographic stations south of Newfoundland and extending to a depth of 750 meters which are quoted by Smith (4. 1926). One station lies north of the Gulf Stream and the other within it. If the allowance for compression were left out from the calculations, the omission would lead to an error of less than 3 per cent. in the calculated velocity of the current. When, however, the hydrographic stations lie many miles apart in waters of very different temperatures and salinities and extend to great depths, the effect of compression upon the final result of the calculation may be material.

Having obtained the weights of the water columns and plotted them upon a chart (Fig. 3), lines of equal hydrostatic pressure can be drawn for the particular depth chosen.

If it is desired to investigate the change in direction and velocity of the current with depth, a number of arbitrary levels may be chosen, the weights of the unit section water columns from the lowest level to those above it plotted, and lines of equal pressure drawn. This gives a series of charts each showing the direction of the component current at a particular level, which is of course additive to the current existing at the lowest level.

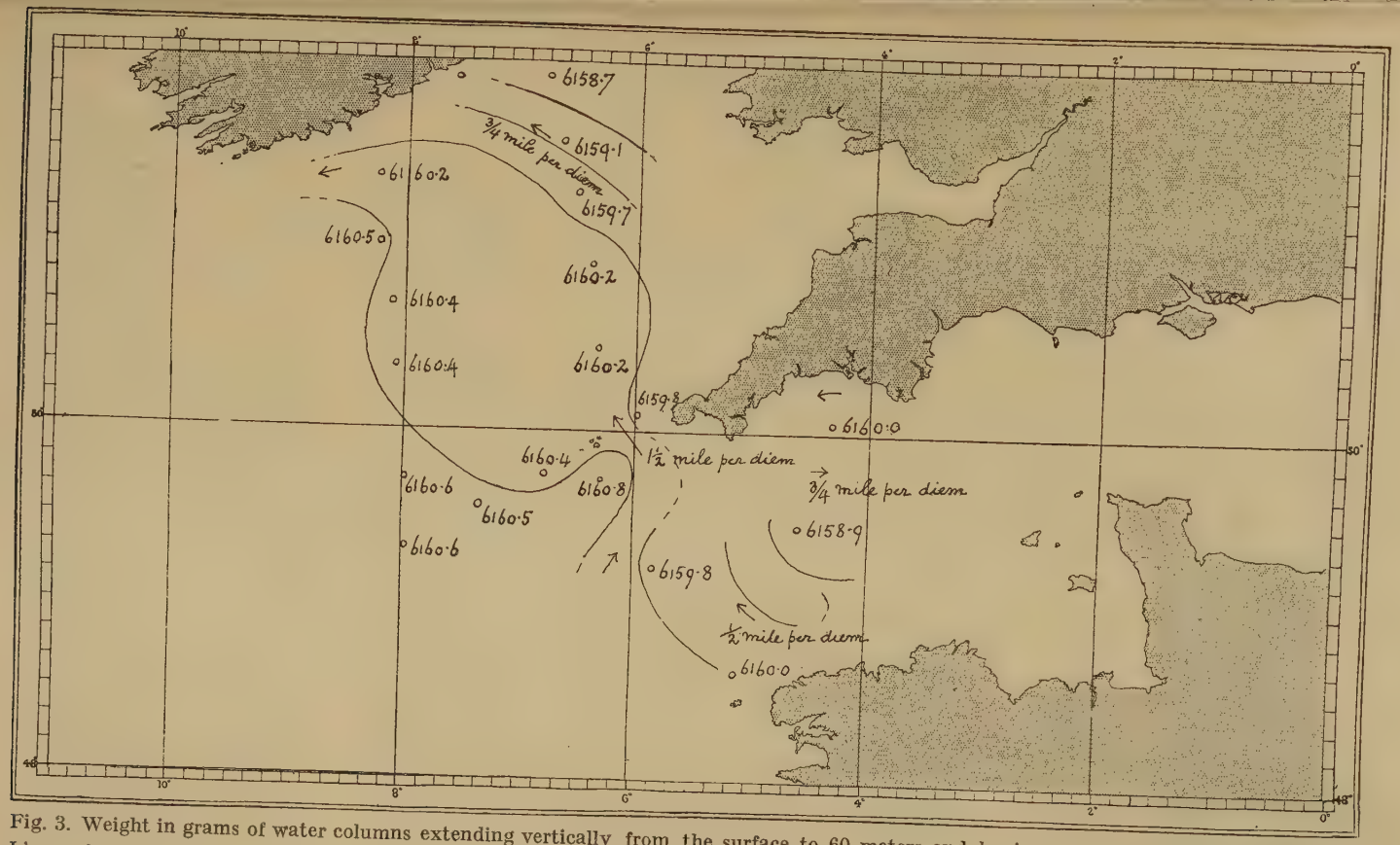

Fig. 3. Weight in grams of water columns extending vertically from the surface to 60 meters and having a cross section of 1 square cm. Lines of equal hydrostatic pressure at 60 meters depth. Calculated differences in velocity between the water at the surface and at the 60 meter level.

The current runs in the direction of the lines of equal pressure, having the lighter water on the right hand side of the direction of flow in the northern hemisphere and on the left hand side in the southern hemisphere. The difference in velocity between the upper level (the surface or some intermediate depth) and the lower chosen level is inversely proportional to the distance between the lines of equal pressure. The difference in velocity may be readily calculated by the formula given on page 86, which is based on the following considerations.

Consider a rectangular vertical section *LPNM* at right angles to a current (Figure 4)

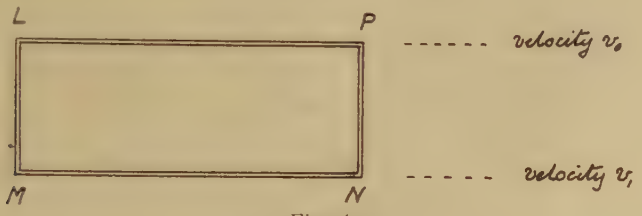

Fig. 4.

the velocity at the upper level *LP* being v_0 and at the lower level, *MN*, being v_1 cms. per second.

Consider a tube of water having unit cross section lying around this section and consisting of two vertical columns *LM* and *PN* and of two horizontal columns *LP* and *MN*.

Let the mass of column $LM = m_1$ grams
Let the mass of column $PN = m_2$ —
Let the mass of all four columns $= m$ grams

Then the force tending to set the water in the tube in motion $= m_1 g - m_2 g$, where g is the acceleration due to gravity. We have, acting in opposition to this force, the deflective force F due to the earth's rotation and friction R.

Hence when equilibrium has been attained

$$F + R = m_1 g - m_2 g$$

or

$$F = m_1 g - m_2 g - R$$

The deflective force of the earth's rotation acting upon the rectangular tube weighing m grams

$$= 2\,\omega v m \sin \text{latitude}.$$

For purposes of calculation the velocity v is taken as the arithmetical mean velocity relative to the water at the lower level i.e.

$$\frac{v_0 - v_1}{2}$$

This value approximates closely to the integral mean velocity of the rectangular tube since the depth of the section is small compared with the distances between the stations.

Hence $$F = 2\omega m \left(\frac{v_0 - v_1}{2}\right) \sin \text{ latitude}$$

$$= m_1 g - m_2 g - R$$

or $$v_0 - v_1 = \left(\frac{m_1 g - m_2 g - R}{\omega m \sin \text{ lat}}\right)$$

The frictional force R is known to be small compared with the other terms and is neglected.

Where the distance between the two stations (at L and P) is great compared with the depth (LM), then m approximates to 2 $LP \times$ mean density of the rectangular tube.

The mean density is always around 1.025 and may be taken at this value without bringing in an error of any consequence. Hence for m may be written 2.05 LP.

Then

$$v_0 - v_1 \text{ approximates to } \frac{m_1 g - m_2 g}{2.05\, LP\omega \sin \text{ latitude}} \qquad (2)$$

for which may be written

$$v_0 - v_1 \text{ approximates to } \frac{36\,(m_1 - m_2)}{D \sin \text{ latitude}}$$

Where v_0 and v_1 are the velocities in cms. per second of the current at the upper and lower chosen levels, m_1 and m_2 are the weights in grams of columns of water at the two positions, having a cross section of one square cm. and extending vertically from the upper to the lower chosen level, and D is the distance between the two positions in nautical miles.

This simple calculation gives the current resulting from the internal field of force.

It is of interest to compare approximation (2) with the equation arrived at by BJERKNES' theory, the term R being likewise neglected (3. 1918). This may be written

$$v_0 - v_1 = \frac{A}{2\,\omega LP \sin \text{latitude}}$$

where

$$A = LM \cdot g \left(\frac{1}{\varrho_2} - \frac{1}{\varrho_1}\right)$$

and ϱ_1 and ϱ_2 equal the mean density of the water in the columns LM and PN respectively,

or

$$v_0 - v_1 = \frac{LM \cdot g\ (\varrho_1 - \varrho_2)}{2\omega LP \sin \text{lat}\ (\varrho_1\, \varrho_2)}$$

Taking the mean density as around 1.025, the term $\varrho_1 \varrho_2$ may be written 1.05 without bringing in an error of any consequence to the final calculation of velocity difference.

$$v_0 - v_1 \text{ approximates to } \frac{LM \cdot g\ (\varrho_1 - \varrho_2)}{2.1\ \omega LP \cdot \sin \text{latitude}}$$

While (2) may be written in the form

$$v_0 - v_1 \text{ approximates to } \frac{LM \cdot g\ (\varrho_1 - \varrho_2)}{2.05 \omega LP \sin \text{latitude}}$$

Hence the calculated differences of velocity are not likely to vary by more than 3 per cent., an error which is quite immaterial.

I am indebted to Professor WERENSKIOLD for an entirely different reasoning which leads to the same result. Let MN in Fig. 5 represent a level of equal hydrostatic pressure, not as in the previous consideration a level of constant depth. Let ϱ_1 be the mean density of the vertical columns of water LM, and ϱ_2 be the mean density of the column PN. LP may be either the surface of the sea or another level of equal hydrostatic pressure. Where ϱ_2 is less than ϱ_1, LM will be a trifle less than PN (Figure 5). LP will be inclined at an angle θ to the horizontal owing to lighter water being piled up on one side of the current.

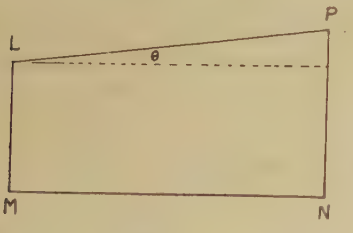

Fig. 5.

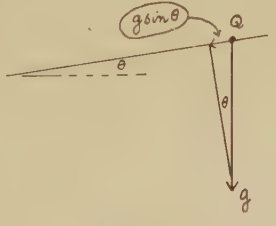

Fig. 6.

$$\frac{LM}{PN} = \frac{\varrho_2}{\varrho_1}$$

$$\therefore PN - LM = \frac{LM\,(\varrho_1 - \varrho_2)}{\varrho_2}$$

and

$$\sin \theta = \frac{PN - LM}{LP} = \frac{LM\,(\varrho_1 - \varrho_2)}{LP\varrho_2}$$

Consider a unit mass of water at Q. It is acted upon by gravity, and the component force tending to make it slide down towards L is $g \sin \theta$ (Fig. 6).

It is also acted upon by the deflective force due to the earth's rotation. This equals $2\omega (v_0 - v_1)$ sin latitude, and acts in the opposite direction, tending to drive the unit mass of water in the direction LP since LP is at right angles to the current with the lighter water below P. Since the section represents a condition where both the current and distribution of density have attained a state of equilibrium these two forces acting in opposite directions upon a unit mass of water at Q must be equal. Therefore

$$g \sin \theta = 2\omega (v_0 - v_1) \text{ sin latitude}$$

or $$v_0 - v_1 = \frac{gLM (\varrho_1 - \varrho_2)}{2LP\varrho_2\omega \text{ sin latitude}}$$ and

approximates to $$\frac{m_1 g - m_2 g}{2{\cdot}05\ LP\omega \text{ sin latitude}}.$$

The Area South East of Ireland.

In the area under consideration a depth of 60 meters has been chosen, this being well below the depth at which a marked change in temperature takes place during the summer months. It is not supposed that currents cease to exist at this depth. The lines of equal pressure (Fig. 3) provide no information concerning the movement at or below this depth. They merely indicate the component current which arises above the 60 meter level and maintains the internal field of force due to density differences. The total current at the surface is the resultant of this component and of any current which exists at 60 meters.

In many areas of the deep oceans it is possible to arrive at an approximation to both direction and velocity of the upper layers, since at 700 to 1000 meters horizontal movement is relatively small, perhaps negligible in many areas. Calculated values have been found to agree well with direct observations in the waters off the Grand Banks of Newfoundland (4. 1926).

So far as I am aware this method of computing the component of the current system which arises in the upper layers has not been applied to relatively shallow waters where the currents are only very slow ones. Hence it is interesting to see how the currents arising in the upper strata, as indicated by this method, in the area south-east of Ireland, compare with our knowledge of the general drift of the whole body of water over the bottom, based as it is upon entirely different premises. The data collected by the s.s. "Muirchu" and the s.s. "Salpa" at the end of June and beginning of July, 1924, are satisfactory for this purpose.

Matthews concluded from the distribution of salinity that a current ran north or north-east between Lands End and the Scillies (1. 1913). The trend of the lines of equal pressure shewn in Figure 3 suggest that the surface water runs about NNE at a velocity of *circa* $1^1/_2$ miles *per diem* over the water at 60 meters, concerning the movement of which no information is afforded by these considerations of pressure distribution.

A cyclonic circulation in the southern entrance of the Irish channel was also deduced by Matthews, and Figure 3 indicates such a cyclonic flow arising in the upper layers as a component of the currents which may exist at 60 meters.

A series of investigations have shown a slow intermittent current running up the English Channel, for the most part south of the middle line in the western entrance. This is not indicated as taking place more rapidly at the surface than at 60 meters in Figure 3 — in fact a component in a north westerly direction is indicated. At this time (June, July, 1924) there is reason to suppose that Atlantic water was slowly entering the channel to pass, after considerable admixture, through the Straits of Dover into the North Sea (2. 1926). Hence it may be inferred that water entering the English Channel north of Ushant and creeping eastward had a north westerly component in the upper layers of about $^1/_2$ a mile *per diem*. In this connection it is significant that several observers have concluded that more water enters the English Channel than passes out into the North Sea, part turning back and running northwards towards the Scillies.

Suitability of Data for Calculation of Velocity Differences.

In dealing with the data collected in the area south east of Ireland, it has been tacitly assumed that these represent the mean conditions at each station during this June-July period. However the water in the area is subject to more or less strong tidal streams extending from the surface to the bottom. At a number of positions where the velocity of tidal streams has been observed at different depths, some variation with depth has been found. It is conceivable that such occurs in this area, and, although the streams run in one direction for a few hours only, they may in that time deform the surfaces of equal pressure, provided of course that there is a difference in their velocity between the surface and 60 meter level. Also in a number of cases it has been found that where a marked discontinuity layer occurs it is constantly undulating. Observations made in July 1923 at station E_1 in the English

Channel indicated that slight undulations of the discontinuity layer occur in this area. A rise in level of about 2 meters was observed to take place in 6 hours, but the observations did not extend over a sufficient length of time to gauge the period and amplitude of the undulation; a breeze sprang up and the rolling of the ship did not allow samples and temperatures to be taken at precise depths. Hence it is possible that data collected at some of the stations do not give the mean conditions, but were taken at an hour when the crest or the trough of an undulation of the discontinuity layer was passing under the ship. Where hydrographic data are being collected with a view to investigating the internal field of force and calculating the currents maintaining it, it is desirable to obtain a series of data at intervals over 24 hours or more, at some of the hydrographic stations, in order to ascertain the period and amplitude of undulations in the discontinuity layer (submarine waves), should such occur. This was done at a number of stations in the Atlantic by the "Meteor".

Effect of Wind blown Currents on the internal Field of Force.

Whatever agency causes a body of stratified water to be set in motion, the deflective force due to the earth's rotation will give rise to deformation of the layers of equal pressure and so set up an internal field of force.

The conditions frequently occurs where the upper 5 or 10 meters of the sea is homogeneous, while marked layering commences below this level. Wind by friction drives the surface layers forward with a material velocity. This can be seen by pouring a little condensed milk, diluted with sea water, from a height into the sea, when it penetrates to some depth; the upper layers run to leeward leaving the water at one or two meters depth apparently stationary. After moving no great distance near the surface the discoloured water is seen to be diluted and mixed with water from below. In such a condition of events the

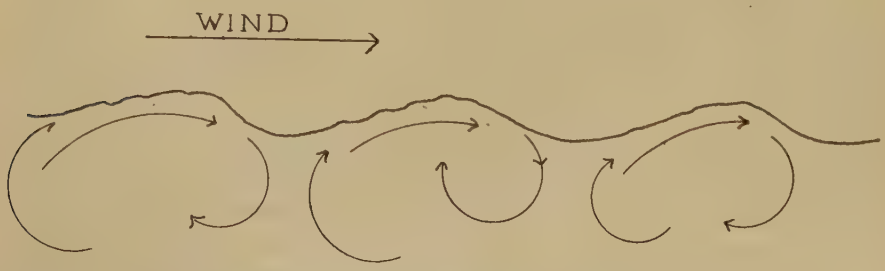

Fig. 7. Diagram illustrating turbulent rolling motion imparted to a homogeneous stratum by wind.

actual difference in velocity between the surface and the water at 5 meters depth may be considerable, but the movement of the upper meter layer as a body be inconsiderable, the forward moving water apparently falling to be replaced by water from below. The energy imparted to the surface is presumably dissipated as heat produced by turbulent motion in the stratum.

In this case there is no steady translocation of the water as a current in the surface meter layer although the velocity may be considerable, and objects within it be carried along at this velocity. It is clear that the only deformation of the surfaces of equal pressure, which will be brought about by this condition, will be those due to the translocation of the water. Conversely, the internal field of force gives no evidence by which the velocity can be calculated at which partly or wholly submerged objects are carried in a surface wind drift, but it does give evidence by which the translocation of the body of water in the upper layers can be calculated, relative to the underlying strata.

The case of on-shore and off-shore winds also deserves consideration. Wind blowing directly on-shore will tend to pile up and thicken the lighter strata against the shore. The external force due to friction of the wind on the sea surface acts towards setting up a current to the right of the wind's direction which, deflected by the shore, will run parallel to the shore line, its velocity diminishing with depth. Such a current will be deflected by the rotation of the earth to the right of its course and in consequence tend to thin the lighter strata on the shoreward side. The field of force then existing will be resultant of the effect of the wind in piling up the lighter strata against the shore, reduced by the forcing to seaward of this lighter water by deflection of the wind impelled current.

This resultant internal field of force, maintained by the surface water constantly being blown in from seaward, gives rise to a velocity difference between the upper and lower strata. The friction of the wind drives the surface water in an opposite direction to the direction of motion which would be imparted to the upper stratum by the internal field of force.

In this case, as with an off-shore wind, deductions based on the internal field of force only tell part of the story.

I am greatly indebted to a number of friends and colleagues particularly to Professor H. U. Sverdrup, who has read the draft of this paper in two stages of its evolution and made many helpful suggestions.

Summary.

A simple method is described of calculating the velocity and direction of ocean currents from the distribution of density in the sea.

The currents, set up by differences in density, in the upper 60 meters of the sea lying to the south east of Ireland, form a current system which is similar to the movement of the whole body of water as deduced by MATTHEWS from the distribution of salinity.

The application of BJERKNES' Circulation Theory to this area, subject only to extremely slow currents, yields results which conform with conclusions based on entirely different evidence.

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An Oceanographical Slide Rule.

A new apparatus for calculating oceanographical data.

By

Oscar Sund,

Fisheries Office, Bergen.

The basic data for calculating the different oceanographic values are:

1) Depth.
2) a) Reversing thermometer reading.
   b) Auxiliary — —
3) a) Burette reading of sea water sample. (a)
   b) — — - normal water
   c) Chlorine content - — —
   Difference of b and c..... (α)

It is now required to calculate salinity, specific gravity and/or volume at 0°, either considering temperature alone or both temperature and depth, i. e. the magnitudes: —

$$S\,{}^{0}/_{00}$$
$$\sigma_0\,,\ v_0$$
$$\sigma_t\,,\ v_t$$
$$\sigma_{t,\,p}\,,\ v_{t,\,p}$$

These calculations require a considerable amount of tedious work, entailing the use of several tables, in some of which even cross-interpolations have to be performed. Apart from the vexatious nature of the latter operation, some amount of error may creep in owing to the necessary neglect of minor fractions even if every operation is correctly made.

In order to simplify matters and to save unnecessary work I prepared, some years ago (see this Journal Vol. I, p. 235) graphical tables

for calculating corrections to reversing thermometer readings and for calculating v_t and $v_{t,p}$. The first-named of these tables have proved entirely satisfactory and is in general use. The graphs for calculating v_t and $v_{t,p}$ have not, however, satisfied me completely, as their use puts an undue strain on the eyes if the values are to be computed with the utmost accuracy, and because $S\,{}^0/_{00}$ has to be calculated numerically beforehand, although a very substantial amount of work was saved.

To obviate these difficulties I have now worked out a new set of graphs based on slightly different principles, doing completely away with numerical work (apart from the finding of α) so that any or all of the required magnitudes can be found in a few seconds and more accurately than by the use of numerical tables.

The new system is made to a very open scale, every hundredth in σ being represented by a distance of 5 millimetres.

The scales cover the following values of the different magnitudes:—

α	+ 0.15	to	— 0.15
a	12.28	to	22.11
$S\,{}^0/_{00}$	22.40	to	39.80
σ.....	18.00	to	32.00
T	— 2°	to	25°
D.....	0 m	to	all depths where any possible combinations of T and $S\,{}^0/_{00}$ can occur.

The relations between the various magnitudes were computed for all integer values of $S\,{}^0/_{00}$, a and v from the formulas given in Martin Knudsen's Tables and from the tables by Hesselberg and Sverdrup (Bergens Museums Aarbok 1914—15, no. 4). The values in the latter tables were treated graphically to avoid steps.

The values for every hundredth in $S\,{}^0/_{00}$, a and v were plotted individually, exactly to the 3rd place, being obtained from an adding machine, the 1st and 2nd differences having been first computed to the fourth place. The σ-scale has uniformly 0.5 cm between the marks.

The graph (3) is a representation of the magnitude D in Knudsen's Tables. D is given by Knudsen to the 3rd place, but for integer degrees only. The values for each 10th part of a degree were computed by the ordinary procedure of subtabulation, using the 3rd, 2nd and 1st differences. The values of D computed by Knudsen for 5°, 10°, 15°, 20° and 25° were computed anew from his formulas, and found correct, as might be expected.

The new system (Fig. 1) consists of 4 graphs:

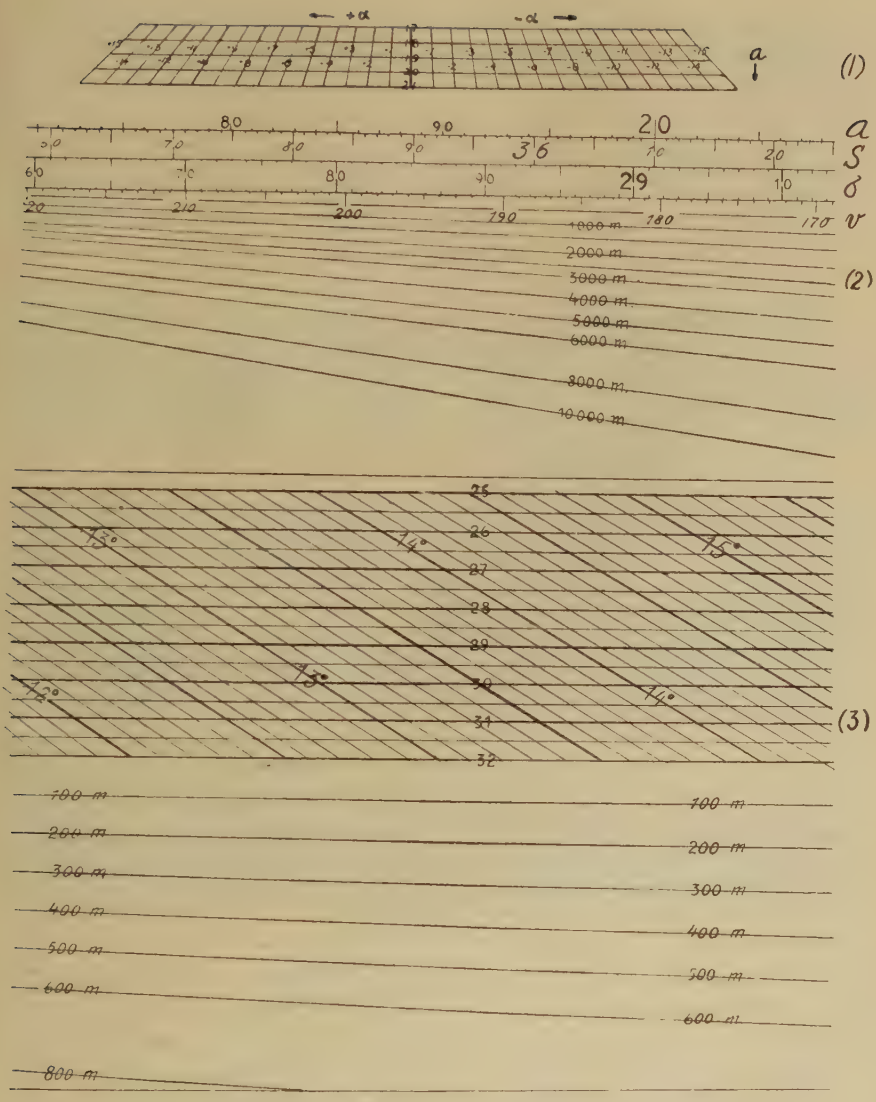

Fig. 1. Portions of the graphs (1), (2) and (3), 0,4 of nat. size.

(1) giving the distance k to be applied to a to find the point in graph (2) lying opposite to the corresponding values of $S\,{}^0/_{00}$, σ and v. This graph is drawn on three different slips (each about 2×20 cm).

(2) Functional scales showing the corresponding values of a, $S\,{}^0/_{00}$, σ and v. Along the edge are drawn functional lines for several depths (in round numbers), the distances of which from the σ, v-scale can

be applied to this, thus introducing the correction $\varepsilon_{S,D}$. The graph (2) has a total length of 7 metres, a breadth of 13 cm.

(3) Functional lines giving the distances to be applied to the σ, v-scale in order to obtain σ_t or v_t. The lines are drawn for every half unit of σ_0 and every tenth of degree C°. Along the lower edge of this line system, which occupies a breadth of about 7 cm, are drawn functional lines for various depths, the distances of which from the base can be applied to the σ, v-scale in order to introduce the correction $\varepsilon_{t,D}$. The graph (3) is drawn on two different sheets, corresponding to σ = resp. 18 to 25 and 25 to 32, — each about 2.5 m long and 20 cm broad.

(4) A scale (not shown in the figures) giving the distances corresponding to the corrections ε_D or δ_p to be applied to the σ, v-scale.

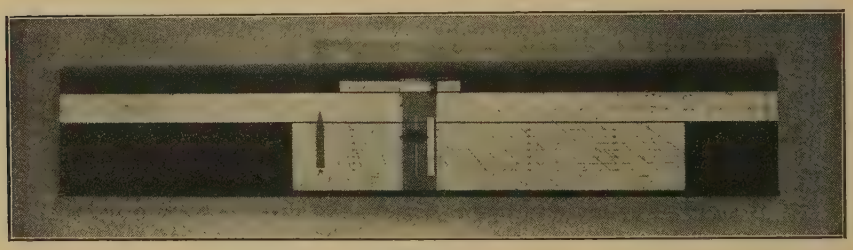

Fig. 2.

The graphs (2) and (3) are drawn in lengths of one m on tracing cloth, thus occupying a space of nearly 2 sq.metres. Copies of the original are easily printed by contact on white-print or blue-print paper from which the parts have to be cut out and pieced together end to end.

For work in any definite marine area only a portion of the graphs is needed. The dimensions will, therefore, not be so forbidding as might be assumed. The best method to mount the graphs has been found to glue them to a "slide rule" (made of teak or mahogany). The whole system might be accommodated on a slide rule 4 metres long and 45 cm wide, using both sides. For use in Norwegian waters an instrument of only 1.40 × 0.24 m gives room for the necessary portion of the graphs.

This model, which is shown in the two photos (Figs. 2 and 3), consists of 3 parts: the board, carrying the graph (2), the slide, carrying the graph (3) and the runner carrying on its brass head the graph (1) and on its celluloid arm a scale for setting the metal two-way pointer to the required a or $S\,{}^0/_{00}$. The brass head carries also a pointer.

Using the apparatus, one sets first the pointer on the head of the runner to the place on graph (1) corresponding to the given a and α.

Then the runner is moved till the point of the head pointer coincides with the given a. The values $S\,{}^{0}/_{00}$, σ_0 and v_0 can now be read if required. Then the right point of two-way pointer on the celluloid arm is set to the given a and the slide is moved till the given temperature coincides with the lefthand point of the two-way pointer. The pointer fixed at the 0-line of the graph (3) is now seen to point to the corresponding values of σ_t and v_t which may read off if wanted.

In order to obtain $\sigma_{t,D}$ and $v_{t,p}$ one has to use a pair of compasses

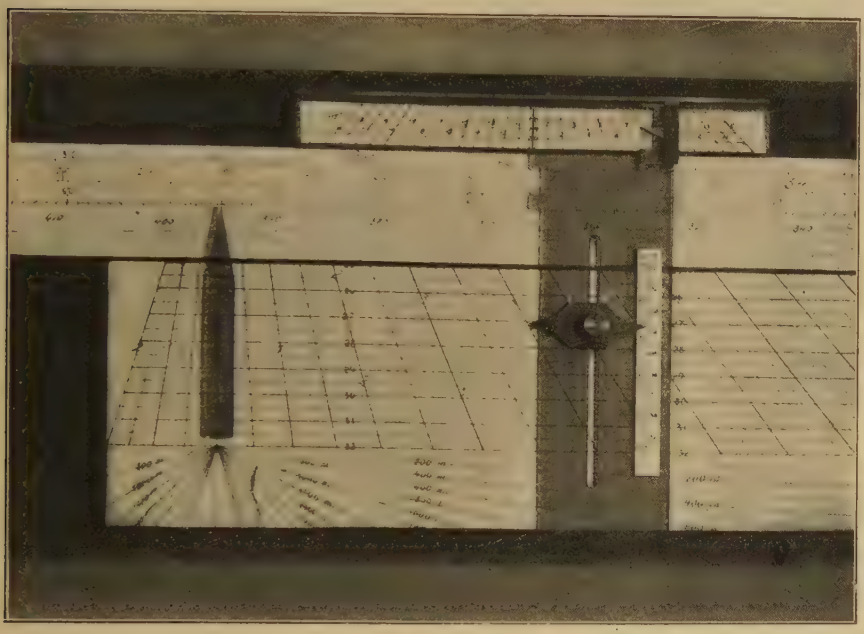

Fig. 3.

and to take the distances corresponding to $\epsilon_{t,D}$ from the resp. base lines of graph (2) and (3), adding or summing them as their sign may require. The sum or difference of these distances is then spanned from the 0-pointer of the slide along the σ, v-scale, to the right or left according to the sign.

The values of v found by applying the correction distance $(\epsilon_{t,D} + \epsilon_{S,D})$ are only correct (within the possible limits of accuracy) when this distance is less than about 3 cm. If greater, it has to be reduced by 3 percent and will then represent $(\delta_{t,p} + \delta_{S,p})$.

The values of σ and v so found are sufficient for calculating gradients. If the absolute values $\sigma_{t,D}$ and $v_{t,p}$ are required, graph (4) must be applied, — always to the right, thus giving $\sigma_{t,D}$ and $v_{t,p}$. For depths greather than 3—400 m the operation is better done numerically.

The position of the different parts shown in Fig. 3 corresponds to the following data: $\alpha = -0.080$, $a = 18.695$, $t = 4.00$, depth 200 m. This gives the following readings: $S = 33.67$, $\sigma_o = 27.055$, $v_o = 365.7$ (i. e. 0.973657), $\sigma_\tau = 26.75$, $v_t = 394.7$, $\sigma_{t,D} = 27.71$ and $v_{t,p} = 303.7$.

A "slide rule" of this description for any portion of the graphs, within the limits given above or prints and runner only, may be obtained from the instrument firm J. Solberg Hansen, Bergen. A later model accommodates the whole of graph (2) on 7 separate, movable rods, each one meter long.

This oceanographical slide rule has been ordered by the Geophysical Institute, Bergen, and by the Marine Observatory, Kobe. It has been in use for some time by our own staff who found it easy and simple in use.

Patterns for Conical Silk Plankton-Nets of one Meter and Half-Meter Diameters.

By

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Carnegie Institution of Washington, U. S. A.

In planning the silk plankton-nets for the seventh cruise of the "Carnegie" some tedious calculations were necessary to prepare suitable patterns. Not only must the size and shape of the net be considered but the number of seams should be as few as possible and arranged for most economical cutting of the silk cloth. This experience in making patterns indicated the desirability of publishing detailed data regarding meter nets and the half-meter nets made for the "Carnegie" for the use of future investigators.

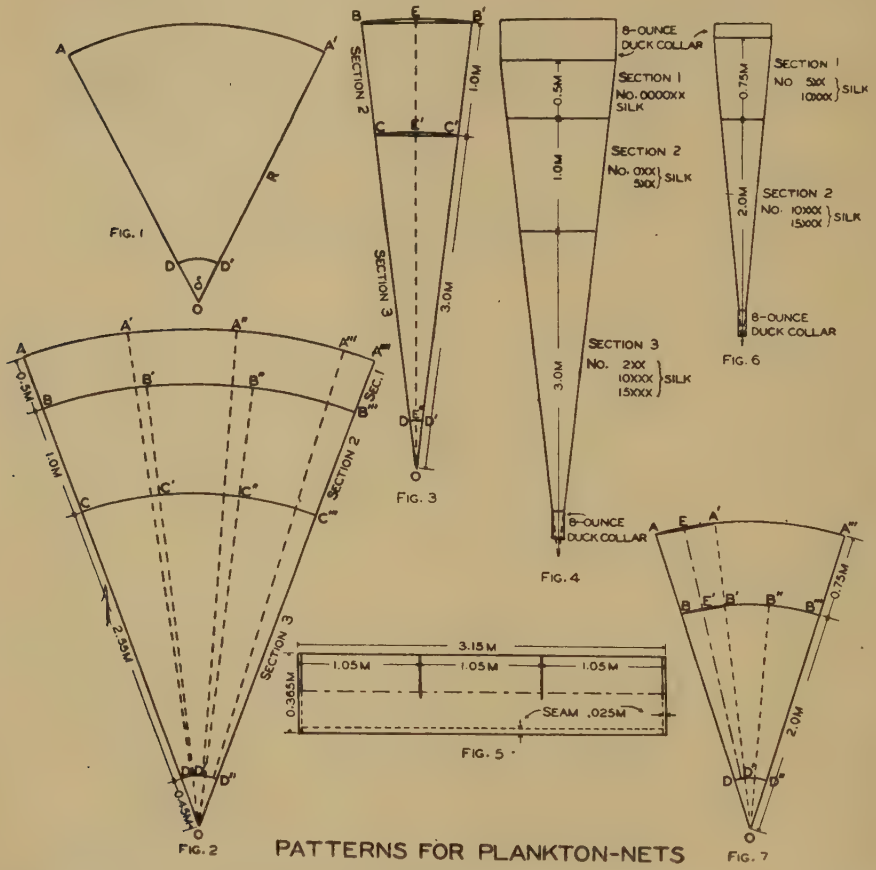
The nets are of sizes (*a*) one meter diameter and $4^1/_2$ meters long (the "Michael Sars" net), and (*b*) one-half meter diameter and $2^3/_4$ meters long. Both were made from silk bolting-cloth of different meshes with canvas-collars at the top and bottom to hold the net-ring and collecting bottle, respectively. The nets (*a*) were made in three different meshes and the nets (*b*) in two different meshes since the filtering characteristics of a net must be according to the kind of plankton to be collected.

Dufour silk bolting-cloth of sizes 0000(XX), 0(XX), 2(XX), 5(XX), 10(XXX), and 15(XXX) was used exclusively for the filtering surface, and eight-ounce double-filled, white, extra duck for the canvas-collars. The seams were taped with inch-wide, fine woven linen or cotton tape, and the silk was sewed with the best quality No. 0 machine twist-silk thread. Fine woven cotton tape $1^1/_2$ inches wide was used for the three-meter horizontal seam which also served to hold the small brass rings to guide the throttle-line. One-inch pearl buttons of good quality were sewed with a strong linen thread to the double canvas-collar, all button holes being machine-made.

The one-meter (outside diameter) brass rings for nets (*a*) were made of three-quarter-inch rod and the half-meter (outside diameter) brass

rings for nets (*b*) of half-inch rod. The silk pieces were joined together by a one-inch French seam, which was taped on the outside and held in place by two additional rows of stitching.

The conical net, developed on a plane surface, is represented by the



sector of a circle (Fig. 1) with radius, R, equal to length of net. The arc $AA' = 2\pi r = \frac{2\pi R\delta}{360}$, where δ is the angle subtended by the arc and r the radius of the net-mouth. Hence:

$$\delta = \frac{360\, r}{R} \qquad (1)$$

To construct the pattern (Fig. 1) it is only necessary to lay off on paper of proper dimensions the sector, OAA', of a circle with center, O, and radius, R, the arc, AA', subtending the angle, δ, as determined from (1). Likewise with radius

$$S = \frac{360r'}{\delta} \qquad (2)$$

where r' is the radius of bottom cup, the arc, DD' is described. The actual pattern for the silk is now $ADD'A'$.

In making the pattern for the upper canvas-collar, a rectangle is constructed with sides equal to $2\pi r$ and having a height equal to the depth of collar plus an allowance for the ring. Similarly for the lower canvas-collar which holds the collecting bottle, a rectangle is constructed with sides equal to the circumference of the lower circle ($2\pi r'$) and height equal to the depth of the collar.

For these patterns it must be remembered, when cutting the silk and canvas, that the areas marked out represent the actual areas of the net, so that it is necessary to add two and one-half to five centimeters to each piece cut to allow for the seams.

This pattern will serve very well for small conical nets (about one-third meter in diameter and one meter in length). In cases where the net is larger the best method followed is to lay out a small sector which represents a fractional part of the whole (such as one-half, one-third, one-fourth, etc.) and to cut the silk pieces from this as illustrated below.

Three sizes of silk were used in making the "Michael Sars" net one meter in diameter at the mouth, tapering to a diameter of 0.10 meter, and 4.5 meters long, with sections as illustrated in Figure 4, in the following combinations.

Section	Combination		
	1	2	3
1.....	0000 (XX)	0000 (XX)	0000 (XX)
2.....	10 (XXX)	5 (XX)	0 (XX)
3.....	15 (XXX)	10 (XXX)	2 (XX)

From (1) for $R = 4.5$ meters, $r = 0.5$ meter, we have $\delta = 40°$. As explained above we may lay down the 40° sectors AOA'''', BOB''', and COC''' with radii equal to 4.5 meters, 4 meters, and 3 meters, respectively (Fig. 2); the arcs divide the sector AOA'''' into three sections, 1, 2, and 3. The canvas-collar at the bottom of the net has a diameter of 0.10 meter ($r' = 0.05$), so from (2), $S = 0.45$ meter = radius for arc DD''.

As sections 1, 2, and 3 each represent a pattern for a different mesh silk, it is necessary in a net of this size that they be divided into parts suitable for the width of the cloth to be cut. The patterns should be of such sizes that the silk may be cut in an economical manner and at the same time have as few seams as possible, all of which radiate from the center.

The 40° sector was divided into three equal parts ($\delta = 13°20'$) BOB', $B'OB''$, and $B''OB'''$. Figure 3 represents one of these three equal parts in which computed values are $CE' = 3 \sin 6°40' = 0.3483$ meter and $CC' = 2CE' = 0.697$ meter, and $DE'' = 0.0522$ meter and $DD' = 0.104$ meter; the lengths for the pattern are made 0.747 and 0.154 meter, respectively, account allowance for seam of 0.025 meter on each side. Two parts COC' can be cut from a single width of silk cloth one meter wide; thus about 8.5 linear meters of silk one meter wide suffice for the six pieces required for section 3 in two nets of this size with allowance for seams. Similarly for section 2 (Fig. 3) $BE = 0.464$ meter and $BB' = 0.928 + 0.05$ (seam) $= 0.978$ meter. The three pieces needed for one net for this section (including material for seams) require 3.3 linear meters of silk cloth one meter wide.

In section 1 (Fig. 2), the chord AA' being taken at 0.95 meter (thus for cloth one meter wide leaving 5 cm. for seams), the angle AOA' is found to be 12°06′, whence the angle $A'''OA''''$ in excess of three equal parts for the section is 3°42′ and the chord $A'''A''''$ is 0.29 meter to which must be added 5 cm. for seams. For all four pieces required for section 1 (allowing 2.5 cm. on all sides for seams) three and one-third pieces of meter-wide cloth about 0.70 meter long are needed.

Figure 5 illustrates the method of making canvas-collars using canvas 73 cm. wide. From this a piece $3.15 + 0.05$ (seam) $= 3.19$ meters is cut. which is then doubled, making its width 0.365 meter, and 2.5 cm. of this doubled cloth is used for the seam where the canvas joins the No. 0000(XX) silk, the remainder (0.34 meter) being doubled to form a pocket for the ring. The final result is a canvas-collar 0.17 meter wide. After the canvas has been first doubled cuts are made 1.05 meter apart to a depth of 0.20 meter so that they extend about 3 cm. below the second fold. When the double-folded collar is closed and fastened to the net the slits will be 120° apart, which makes three flaps. Eighteen buttons, evenly distributed close to the margin of the collar, permit the flaps to be fastened in place and hold the ring.

The lower canvas-collar is a simple rectangular piece of canvas $0.10\pi = 0.314 + 0.05$ (seam) $= 0.364$ meter long and 0.25 meter $+ 0.025$ (seam) $= 0.275$ meter wide. This collar, which is not doubled, is sewed to the lower silk part of the net.

Two sizes of silk are used in the one-half meter net which is one-half meter in diameter at the mouth, tapering to a diameter of 6 cm., and has length $R = 2.75$ meters. The divisions are illustrated by Figure 6, from which the following combinations were made: (1) Section 1 of

5(XX) and section 2 of 10(XXX) silk; (2) section 1 of 10(XXX) and section 2 of 15(XXX) silk.

Using the same notation as above for $R = 2.75$ meters and $r = 0.25$ meter, from equation (1) $\delta = 32°44'$. The pattern is marked out in essentially the same way as the "Michael Sars" net by laying out the parts as shown in Figure 7, the total area of the silk part of the net being divided into sections 1 and 2. The radius of DD'' by equation (2) for $r' = 3$ cm. is 32 cm.

For convenience, sections 1 and 2 are considered as one and divided into thirds, one of which is used, as before, as a basis for computation. In section AOA' (Fig. 7), the chords AA', BB', and DD' computed as before are 0.523, 0.381, and 0.06 meter, respectively, which with seam-allowances become 0.573, 0.431, and 0.11 meter.

The part $AA'B'B$ (Fig. 7) serves as a pattern for the upper 0.75-meter section of the net; the three pieces cut to this pattern in the most economical manner require one and one-half pieces about 0.90 meter long of meter-wide silk cloth, having allowed for seams on all sides. $BB'D'D$ is a pattern of the lower two-meter section 2 for which three pieces of silk the same size as $BB'D'D$ plus 2.5 cm. on all sides for seams are needed, and all of which can be cut from one piece of meter-wide silk cloth about 2 meters long.

The canvas-collars are made in essentially the same way as in the "Michael Sars" type. The upper collar is cut from 0.73 meter-width, eight-ounce duck and is $0.5\,\pi + 0.05$ (seam) $= 1.62$ meter long. This piece is doubled and three slits spaced 0.52 meter apart are cut to a depth of 0.20 meter. The piece is then redoubled as before, and when the collar is closed the slits are spaced 120° apart, forming three flaps which button the ring in place. For this half-meter net there are only 12 buttons (four for each flap) fastened to the margin of the collar. The lower collar is cut as a rectangular piece, $0.06\,\pi + 0.05$ (seam) $= 0.24$ meter wide and $0.25 + 0.025$ (seam) $= 0.275$ meter long. This is sewed to the lower edge of the silk and, when completed, forms a circular collar 0.06 meter diameter and 0.25 meter long.

Note.

Apparatus for measuring Fish.

By

Professor **D'Arcy W. Thompson.**

The method of measuring fish which Mr. H. J. B. Wollaston describes in the last number of this Journal is practically identical with one which I devised twenty five years ago, for our work under the Fishery Board for Scotland. The main idea was to record the measurements by holes pricked in a sheet of paper; the next was to use squared (millimetre) paper for this purpose, so that the sizes could be read off at once from the pricked sheet. The measuring-board is covered with cork; it has a ledge at one end against which the fish's head is set; the sheet of squared paper lies in its place on the corked board; and it is the work of an instant to lay the fish down, to draw the flaps of its tail-fin together, and to mark their place by means of a pin-point held in a conveniment handle. The board and the squared paper covering it are made of a good size, say 18 or 20 inches broad, so as to allow of two or three hundred measurements being made without the pinholes interfering with one another. We soon found it convenient to lay a sheet of plain paper over the squared paper, in order to keep the latter clean; and the last improvement was to use waterproof paper for this purpose. The pricked sheets are filed, like other papers; and the number and sizes of the fish can be read off at any time.

Correspondence.

The Rearing of Lobster Larvae at Flødevigen.

1.

In *Journal du Conseil*, Vol. III, No. 3, Professor A. Meek has given a review of my report on lobster culture (Bergen 1928).

On reading the review, however, I was greatly astonished to find that it contained very little of the results obtained by me — and what it did contain was apparently perceived through coloured glasses.

The honoured Professor states that the survival to the 4th stage of the lobster larvae in my experiments amounted to about 14 per cent. The data given in my paper show that the survivals in the experiments, brought to a proper conclusion, varied between 28 and 35 per cent. In order to get at 14 per cent. the reviewer has taken the totals of the young dealt with, and the totals of the 4th stage larvae — but omits to mention the larvae in other stages (about 37 thousand) which had to be liberated on the 22nd of August. At that date the rearing experiments had to be discontinued, the money granted to the work having come to an end.

The reviewer finds that it is "manifest" that considerable loss takes place at two periods, first of the eggs during the transport of the berried lobsters, second of the larvae on the approach of the 4th stage. As to the first point I have mentioned that many eggs are lost in the boxes where the lobsters are kept alive (by the merchants). And as the lobsters are not taken to the hatchery before the first week of July many eggs are hatched before that date.

I say nothing as to the loss in transport!

The second point is not mentioned at all in my report, and no details whatever are given on which such a conclusion can be based!

What Professor Meek states about the mortality of lobster larvae in nature is very interesting. I should be very pleased, however, to see the scientific data on which his opinion is based.

The results of lobster culture during the season 1928 are the following:

July 2nd—August 24th. Collected..	222.629 larvae	
Put direct into the sea, the rearing boxes being too few	74.030 —	
Used for rearing experiments	148.599 larvae	
Reared to 4th stage	50.187 —	= 34 per cent
Put into the sea, mostly 3rd stage at the termination of the work....	6.826 —	

The berried lobsters amounted to 200 and were bought from a lobster merchant on the 28th of June, too late to secure the full number of eggs.

The Flødevig Sea-fish Hatchery,
Jan. 30th 1929.

Alf Dannevig.

2.

I do not have Mr. Dannevig's paper at hand, but in my review of it I stated that he had obtained better results than his predecessors. As scientific experiments such attempts are interesting, but it is necessary also to realise the futility of such methods as a means of improving a lobster fishery.

The results of artificial rearing should obviously be much better than can be presumed to occur in nature. Let us take the above figures, which are admittedly as good as have been obtained by anybody. The larvae hatched from the lobsters were a little over 1000 per lobster, and if we assume that the eggs carried numbered on the average 40,000, this amounts to a survival of 2.5 per cent. in about a year. After a further period of free life of say a month, this number is reduced by 66 per cent. or to about 1 per cent.

Even if we neglect the loss by transport of the berried females and other causes, a survival of 34 per cent. after a few weeks of free life is plainly quite inadequate.

If Mr. Dannevig will consult my paper "On the Crustacea" in the Report of the Dove Marine Laboratory, new ser. VII, 1918, pp. 40, 41, he will see why I believe that tank rearing has a detrimental effect on the growth of young lobsters.

Armstrong College Newcastle-upon-Tyne,
7th Feb., 1929.

A. Meek.

Reviews.

H. W. Harvey. Biological Chemistry and Physics of Sea Water. Cambridge University Press, 1928, pp. x + 194.

This book deals with those parts of chemical and physical oceanography which are of special interest to the biologist but are treated in a somewhat condensed fashion in the standard treatises on the subject. The examples are drawn chiefly from the North Atlantic and the northern European seas, but the principles are of universal application. The opening chapter deals with the algae and phytoplankton which are the starting point of the cycle of life in the sea, since they alone are able to make use of the radiant energy of the sun. They require a suitable temperature, light, carbon dioxide, nitrates, phosphates and silicic acid for their development, and each of these appears to be at times a limiting factor, except perhaps the last. The productivity of temperate seas is immense; Atkins has calculated that the annual minimum production in the English Channel is 1400 metric tons per square kilometre of surface. The time at which the annual outburst of phytoplankton occurs here depends on the increase of sunshine in February or March, while the date at which animals, such as larval fish, require the diatoms for food depends upon the temperature, which is to a large extent independent of the local sunshine. It thus happens that though the production of phytoplankton may be the same in two years its availability as a food may be very different. Some account of the experiments of Allen and Nelson on the artificial rearing of diatoms is given and might have been extended with advantage.

The second chapter, on the chemistry of seawater, is the most valuable. The method of determining the phosphates by Atkins' modification of Denigès' process is described; it would have been well to add that the colour requires at least five minutes for its development and that it is not constant for more than half an hour. The difficult subject of the excess base, carbon dioxide and hydrogen ion concentration is well treated; the last does not appear to have much effect on the well-being of the fauna in the open sea, but under other conditions, such as are found in hatcheries and aquaria it is of considerable importance. McClendon's table of buffer solutions with the corresponding pH values for water of various salinities is given.

The third chapter deals with tides and ocean currents and with the effect on the latter of wind, density and the rotation of the earth. A correction is required on p. 111. In line 24 the words "in the northern hemisphere" should be omitted, since the statement holds good in southern

latitudes as well. The description of Fig. 30 should run "Cyclonic current formed round a sinking centre in the southern hemisphere", and the corresponding erratum note at the beginning of the book should be deleted. A description of the calculation of the vertical differences of velocity in a current by the method founded on the work of BJÉRKNES by HELLAND-HANSEN and SANDSTRÖM is also given. In the section dealing with temperature the importance of the effect of eddy motion in producing vertical mixing is well brought out, as is also the value of the information to be gained by considering the mean temperature of the whole of a vertical column. An interesting example of this is given in Fig. 54 which shows that in 1921 at a point twenty miles south-west of Plymouth the temperature was the highest recorded, and in addition that this abnormal temperature was reached in October, a month after the mean date of the maximum. The curve is an excellent proof of a strong inflow of water from the Atlantic. A slip occurs on p. 156; 10Å = $\mu\mu$, not μ. The last chapter treats of the general problem of the fertility of the sea, the cycle of life, the importance of the upwelling of water rich in phosphates and nitrates and the question of their ultimate regeneration. It seems possible that the stock of these essentials is being slowly transferred to the depths where they are of no use.

The book contains good bibliographies and gains in value in that it is a product of the Plymouth Laboratory where so much work has been done in these directions since the war. It should be of great use to all interested in marine chemistry and physiology. D. J. MATTHEWS.

H. H. POOLE and W. R. G. ATKINS. Further Photo-electric Measurements of the Penetration of Light into Sea-Water. Journ. Marine Biol. Assoc. XV No. 2, pp. 455—483. 1928.

The paper under review forms a continuation of three former papers, viz.: 1) POOLE, H. H. On the Photo-electric Measurement of Submarine Illumination. Sci. Proc. R. Dublin Soc., 1925, *18*, No. 9, 99—115. — 2) POOLE, H. H. and ATKINS, W. R. G. On the Penetration of Light into Sea-Water. Journ. Marine Biol. Assoc., 1926, *14*, No. 1, 177—198. — 3) ATKINS, W. R. G. A Quantitative Consideration of some Factors concerned in Plant Growth in Water. Pt. I. Some Physical Factors. Journ. du Conseil Internat. pour l'Exploration de la Mer, 1926, I, No. 2, 99—126.

In the paper under review the apparatus is briefly described and an account is given of the improvements so far made. The light-sensitive part of the photometer is a photo-electric cell through which flows an electric current from a battery. The current through the cell being exactly proportional to the illumination with light of a given wave-length, this current is measured. The way in which the current-measurement is made is described. Two kinds of photo-cells were used. The one, a gas-filled potassium-hydride cell of the Kunz type, is more sensitive than the other, the vacuum-cell, but this latter has the great advantage of constancy. Thus it has proved advantageous to use the vacuum-cell from the surface down to about 40 metres in clear water, and to use the gas-filled cell at greater depths. The colour-sensitivity of various cells has been investigated and the result shown in diagrams with the wave-lengths from 4000 ÅU

to 6500 ÅU as abcissæ and the sensitivity as ordinate, taking the maximum sensitivity as unit. The diagrams show that a gas-filled cæsium cell has its maximum sensitivity at about 5300 ÅU, whereas the five other cells investigated have their maximum sensitivity at much smaller wave-lengths, 4300 ÅU or less.

During the autumn September—December of 1927 many investigations were carried out in the Channel at various distances from the sea-shore at Plymouth. The very interesting results of these investigations may be summarised as follows. The opacity of the water most often decreases with increase of depth, although the opposite has also been found. This may possibly be explained by the distribution of the plankton of which the zooplankton makes vertical movements according to the optimum light intensity for each species. The opacity decreases with the advent of winter to such an extent that the coefficient of absorption in December has about half the value of that in September. This is very clearly demonstrated in a diagram in the paper, and is explained by a corresponding decrease in the amount of plankton.

The authors tried without much success to correlate the maximum depths of visibility of a Secchi disc with the absolute and the percentage illumination at that depth. This lack of correspondence is tentatively explained by the special effect of the surface, and the authors are right in stating that the use of a water telescope might possibly lead to more consistent results. The reviewer is of opinion that a special study of the Secchi disc ought to be undertaken in order to compare the maximum depth of visibility with and without the use of a water telescope.

The paper is highly interesting and shows clearly that the authors have been able, not only to construct the rather complicated and delicate apparatus they have employed, but also to use the apparatus on board with much success. MARTIN KNUDSEN.

BIRGITHE FÖYN und H. H. GRAN. Über Oxydation von organischen Stoffen im Meerwasser durch Bakterien. Det Norske Videnskaps-Akad. Oslo. Matem.-Naturv. Klasse. 1928. No. 3.

Towards the end of March 1926, during the height of the spring outburst of diatom growth, water samples from various depths were collected from Romsdal to beyond the edge of the continental shelf, some fifty miles out to sea. Waters of diverse types were obtained. In the fiord, the upper layer, supersaturated with oxygen and rich in diatoms, lies on relatively stagnant deep water about 80 per cent. saturated with oxygen. Here 636 diatoms per cc. were found at 10 meters and only 2 at 75 meters. Outside the fiord, water of moderate depth extends over the continental shelf for some 40 miles to seaward, this water forming the Baltic current running northward along the Norwegian coast. Here some 136 diatoms per cc. were found at 10 meters, while at the edge of the continental shelf 1461 diatoms per cc. were present, the species found in the fiord having given way to *Asterionella* which was also found dominant in the more saline Atlantic water beyond the shelf, where 380 individuals per cc. were found at 10 meters. At each position investigated, plankton organisms

were very scarce at 75 meters and below, plant growth being limited to the upper layers owing to shortage of light below about 10 meters.

The bacteria present in the samples collected were plated out on fish gelatine. In every case the number which formed colonies was very small — an average of some 4 organisms per cc. of sea water except in the water over the edge of the shelf, where the samples contained 11, 3 and 28 organisms at 10, 75 and 300 meters respectively. This suggests upwelling in this region. The same procedure was carried out with the waters after being stored in flasks, when the numbers of bacteria rose to 50 thousand or more per cc. in about a month and then decreased. This effect of storage of water in small vessels upon the development of bacteria is peculiar. It has been investigated in the case of fresh water by WHIPPLE who found a marked relation between the number of bacteria which developed and the size of the bottle in which the water was stored.

The waters were also examined for denitrifying bacteria by inoculating calcium malate nutrient medium with the samples. In two cases gas-forming organisms developed in the medium, shewing the presence of bacteria, both in the Atlantic water and close to the shore, which are capable of bringing about denitrification under certain conditions.

The oxygen contents and pH-values of the waters were determined when they were collected, and after storage for one week, one month and three months respectively. In this way the quantity of oxygen used up during the oxidation of organic matter by bacteria was arrived at. The quantities corresponded very closely with the quantities of CO_2 set free, as calculated from the fall in pH. In the tabulated results, the values shown for $C_{(OH)}$ are subject to multiplication by 10^{-7} and it is not explained how the oxygen used during storage is reckoned from the decrease in $C_{(OH)}$. However by using the data published by MCCLENDON for the relation between pH and total CO_2 in sea water, similar values may be arrived at, assuming that one molecule of oxygen was converted into one molecule of CO_2.

Estimations were also made of the potassium permanganate reduced by organic matter in the waters. These shew that the oxygen, consumed by the substances which are oxidised by permanganate, is greater in the plankton-rich upper layers, but the values do not otherwise shew any obvious relation to the oxygen consumed during the breakdown of organic matter in the waters through the agency of bacteria.

The results of this investigation effect a distinct advance in our quantitative knowledge of organic matter in sea water. H. W. H.

H. M. KYLE. The Biology of Fishes. London, Sidgwick and Jackson, Ltd. 1926. xvi + 396 pp., 17 pl.

KYLE's neuestes Buch unterscheidet sich in erfreulicher Weise von dem, was man dem Publikum gewöhnlich als populär-wissenschaftliche Fischkost vorzusetzen pflegt. Es enthält eine erstaunliche Menge von Einzelbeobachtungen und geistreichen Hypothesen, die in so fesselnder Sprache vorgetragen werden, dass man bei der Lektüre den Bleistift nicht aus der Hand legen kann, sondern fast Seite für Seite sowohl Ausrufe der Bewunderung, als auch bedenkliche Fragezeichen setzen muss.

Doch überwiegen die ersteren bei Weitem! Es ist im Ganzen ein gar vorzügliches Buch, und nur ein Gelehrter, der in einer Weise wie Kyle die Riesenliteratur über Fische und Fischereien des verflossenen Vierteljahrhunderts beherrscht und es ausserdem versteht, das überwältigende Tatsachenmateria unter einheitliche Gesichtspunkte einzuordnen, vermag ein solches Werk zu schaffen.

Voran geht eine kurze Einleitung. Kennzeichnend ist, dass der Verfasser es für nötig hält, gleich auf der ersten Seite seine Stellung zum Darwinismus zu betonen. »The possibility that characters have arisen at variance with the innate tendencies of "Heredity", and persisted without the aid o "Natural Selection", is a thesis which requires some courage to state«. Und er führt sodann aus, wie er auf Grund seiner ichthyologischen Studien zu dieser Auffassung gekommen ist. Von den drei Faktoren, welche die Entstehung neuer Formen in der Natur bedingen: Erblichkeit (heredity), Beweglichkeit (activity) und Einflüsse der Umwelt (environment), hat bei der Entstehung neuer Arten nach Kyle's Meinung der zweite die bedeutendste Rolle gespielt. »The activity of the individual, the link between inheritance and environment, is probably the most important factor in the making and remaking of characters«. Es ist klar, dass hier mit »activity« nicht allein die mechanischen Körperbewegungen, sondern die Gesamtheit der als Tropismen bezeichneten Bewegungsreaktionen der protoplasmatischen Gebilde gemeint wird.

Kyle zitiert sodann einige bekannte und ihm sehr gelegene Aussprüche Darwins, aus denen hervorgeht, dass dieser grosse Biologe es im Grunde genommen für unmöglich hält, zu beweisen, dass sich eine Art geändert hat oder dass die vermeinten Änderungen nützlich sind, und dass er sogar die Möglichkeit zugesteht, dass neue Tiergruppen entstanden sind »through the nature of the organism and the surrounding conditions, but not through natural selection«. Und er fährt fort (ich übersetze): »Diese Behauptungen finden ganz besonders Anwendung auf die Fische und es ist nicht schwer, zahlreiche Beispiele zu nennen, wo Abänderungen gerade das Gegenteil von nützlich sind, und dennoch die Arten am Leben geblieben sind und sich fortgepflanzt haben«.

Die Hypothese von der »Beweglichkeit« der Organismen als wirksamstem Faktor bei der Artbildung bildet nun gleichsam das philosophische Leitmotiv dieses Buchs und wird oft sehr geistreich, hier und da — wie mir scheint — jedoch etwas gezwungen als Erklärung für die erstaunliche Vielgestaltigkeit der Fische herangezogen. Es ist jedoch infolge seiner knappen Schreibweise — übrigens ein nicht hoch genug zu schätzender Vorzug seines Buchs — nicht immer leicht zu verstehen, was der Verfasser meint. So z. B.: »These fishes have not made their structures but their intelligence has been at work in using and developing them in particular directions" (S. 12). Auch Behauptungen wie (S. 125): »If the frogs came from the Lung-fishes (*Dipnoi*), they showed their greater wisdom by at once getting rid of this undesirable character« (nämlich: der Spiralklappe!) geben zu denken.

In vierzehn Kapiteln gibt Kyle in gedrängter Form eine gemeinverständliche Übersicht über das Wesentlichste aus der Biologie der Fische. Die ersten beiden Kapitel sind allgemeinen Inhalts und handeln über die

allgemeinen Eigenschaften und Gewohnheiten der Fische. Im dritten Kapitel werden ihre Wanderungen, im vierten die Entwicklung (Ontogenie) besprochen. Das fünfte Kapitel, das sehr anregend geschrieben ist, bringt des Verfassers Ansichten über die Regulierung von Bau und Form. Kapitel VI und VII tragen die Überschrift: »Economy of the Body«; hier werden die Hauptsachen der Physiologie s. str. erörtert. Das achte Kapitel handelt über Variabilität und Differenzierung mit einer sehr ausführlichen Besprechung von Johs. Schmidt's Rassenuntersuchungen, die beiden folgenden über die Genealogie und Verbreitung der Fische. Das elfte Kapitel enthält eine ausgezeichnete Übersicht über die sogenannten »Anpassungen« der Fische, das zwölfte, »Fishes and the Web of Life«, ebenso vorzügliche Auseinandersetzungen über die Beziehungen der Fische zu einander und zu anderen Organismen (Geschlechtsleben, Kommensalismus, Parasitismus, Krankheiten). Ich kann nicht umhin, die hübsche Einleitung zu diesem Kapitel (S. 289) hier abzuschreiben, da sie ein gutes Beispiel ist von des Verfassers Stil und Gedankengang:

»A single individual is a rogue or an outcast; the phenomena of life require at least two, and around these are the links which bind them to others of the same kind. Further away, but still pressing upon them, are the relations, friendly or hostile, with an infinite number of other forms of life. Apart from the sex problem, it is mainly a matter of food that brings one form of life into touch with another; perhaps "hunger" would express the relations in either case. Then, too, the pursued seek to escape the attention of their pursuers and this leads to other curious relationships. How these express themselves in the case of fishes may be gathered from the following«.

Die Nahrung der Fische und im Zusammenhang damit die neueren Untersuchungen über die »Valuation of the Sea« bilden den Inhalt des dreizehnten Abschnittes, während im letzten das Seelenleben der Fische behandelt wird.

Eine Synopsis der Familien der Fische, ein gedrängtes Verzeichnis der wichtigsten Literatur und ein Index bilden den Schluss dieses mit zahlreichen Tafeln und Textfiguren geschmückten Buchs, das, wie gesagt, sowohl durch Inhalt wie Darstellung zu dem Besten gehört, was in neuester Zeit über die Biologie der Fische veröffentlicht wurde. H. C. R.

A. Bowman. Review of the Cod Net Fishing in the Moray Firth. Fishery Board for Scotland. Scient. Invest. 1928, No. I.

Eine an der schottischen Westküste schon seit etwa einem Jahrhundert bekannte Fischereiart, der Fang mit dem sogenannten »Kabeljaunetz« (cod net), ist seit reichlich 20 Jahren auch im Osten Schottlands, und zwar im Moray Firth, in Gebrauch. Es handelt sich bei diesem Gerät um ein Stellnetz, und da die Anwendung von Schleppnetzen den britischen Fischern im Moray Firth verboten ist, bildet dieses Gebiet gewissermassen einen geeigneten Boden für die Einführung von erfolgreich zu verwendenden Stellnetzen. Der Verfasser zeigt an Hand von Tabellen und graphischen Darstellungen, welche überraschenden Erfolge und infolgedessen auch schnell steigende Verwendung das Netz im Moray Firth gefunden hat.

Die Fangkurve zeigt allerdings einen sehr unruhigen Verlauf, sodass die Vermutung nahe liegt, dass nicht jedes Jahr gleichmässig günstige Vorbedingungen für hohe Fangerträge hat. Es handelt sich nämlich um den Fang reifer Kabeljaus, und deren Eindringen in den Moray Firth erfolgt möglicherweise in den einzelnen Jahren in verschieden starkem Masse.

Dann wird vom Verfasser eine eingehende Schilderung des Netzes und seiner Anwendungsweise gegeben, und dem schliesst sich eine Besprechung der Fischgründe an. Diese liegen zur Hauptsache im nördlichen Teil des Moray Firth, den auch in grösserem Masstabe Fischer aus Ortschaften der Südküste aufsuchen. Wenn auch die Fischplätze im einzelnen von Jahr zu Jahr sich etwas ändern, so liegen doch die besten Plätze zwischen Clyth Ness und Tarbet Ness innerhalb 10 Meilen von der Küste. Die beigegebene Karte zeigt deutlich, dass sich an den angeführten Plätzen die Fänge zusammendrängen. Allerdings sind nur die Fänge von gezeichneten Schollen und Rotzungen (*Pl. microcephalus*) wiedergegeben, und für den Fang von Plattfischen ist das Netz nicht sehr geeignet.

Die Fischerei auf reifen Kabeljau ist auf die ersten Monate des Jahres beschränkt, und der Beginn schwankt in den verschiedenen Jahren. Gewöhnlich sind es die kleineren Boote, die tastend mit dem Fang in den ersten Januarwochen beginnen, und bei reichlicherem Erscheinen reifer Kabeljau vermehrt sich die Beteiligung an der Fischerei sehr schnell. Der Verlauf der Fischerei ist im grossen und ganzen in jedem Jahre ziemlich gleichmässig. Dann wird die Fischerei nach den einzelnen Distrikten behandelt.

Als Fahrzeuge werden in dieser Fischerei Dampfer, grosse und kleine Motorboote sowie grosse und kleine Segler benutzt. Es ist natürlich, dass die Fahrzeuge mit stärkerer maschineller Kraft am erfolgreichsten in der Fischerei sind, zumal diese zu einer Jahreszeit stattfindet, in der der Wettereinfluss gross ist. Die Segelfahrzeuge waren die ersten, die das Kabeljaunetz im Moray Firth anwandten. Ihre Fangerträge stiegen fast ständig, mit Ausnahme eines Jahres (1911) und erreichten im Jahre 1912 ein Maximum, von dem ein fast stetiger Abfall erfolgte, sodass seit dem Jahre 1920 die Anlandungsmengen durch Segelfahrzeuge die kleinsten Zahlen von allen drei Fahrzeugarten aufweisen.

Dampfer begannen erst im Jahre 1909 mit dieser Fischerei und erzielten bereits im darauffolgenden Jahre die Höchstmenge ihrer Anladungen. Diese sanken dann aber in den nächsten Jahren wieder beträchtlich und erreichten ihren tiefsten Stand in den Kriegsjahren. Motorboote haben erst ziemlich spät (seit 1912) an dieser Fischerei teilgenommen, sie haben aber dann sehr schnell an Bedeutung gewonnen und liefern seit 1919 die grössten Fangmengen von allen drei Fahrzeugarten.

Die Intensität der Fischerei wird untersucht nach der Zahl der Anlandungen, wobei wiederum die verschiedenen Fahrzeugarten getrennt behandelt werden. Man ersieht daraus auch, welche Häfen vorzugsweise von Dampfern aufgesucht werden, und welche Veränderungen in dieser Beziehung im Laufe der Jahre vor sich gegangen sind. Bei der Besprechung der Motorboote ist allerdings zwischen grossen und kleinen Motorbooten unterschieden, ebenso zwischen grossen und kleinen Seglern, und die letztgenannten sind mit den kleinen Motorbooten zusammengefasst.

Ein besonderer Abschnitt ist dann noch den Erörterungen über die Schwankungen im Auftreten der Kabeljau innerhalb des Moray Firth gewidmet. Hierbei geht der Verfasser davon aus, dass in der behandelten Fischerei Fahrzeuge von verschiedenen Typen (verschiedener Antriebskraft) und verschiedener Grösse tätig sind, dass aber alle dieselbe Fangmethode ausüben. Ein Unterschied besteht in der Zahl der zu einer Fleet zusammengeknüpften Netze. Deshalb sind bei der Untersuchung über die Schwankungen im Auftreten der Kabeljau auch wieder die verschiedenen Fahrzeuge getrennt behandelt. Der Verfasser erkennt wohl die Schwierigkeiten, die in dieser Berechnungsweise liegen, und ist bemüht, möglichst alle Unsicherheitsfaktoren auszuschalten. Wenn auch, wie der Verfasser betont, die Ergebnisse nur Annäherungswerte sind, so ergeben sich doch ganz deutlich überaus grosse Schwankungen in den Erträgen, die hier im Mittel für 10 Anlandungen berechnet sind. Es zeigt sich, dass die reifen Kabeljau in den einzelnen Jahren nicht nur in verschieden starkem Masse in den Moray Firth eindringen, sondern dass auch in der lokalen Verteilung der Schwärme Abweichungen eintreten. SCHNAKENBECK.

A. BOWMAN. Danish Seine-net Fishing in the Moray Firth. Fishery Board for Scotland. Scient. Invest. 1928, No. II.

Ähnlich wie die Fischerei mit dem Kabeljaunetz unterzieht hier der Verfasser die Fischerei mit der Wade im Moray Firth einer eingehenden Untersuchung nach verschiedenen Gesichtspunkten. Die Einführung der Wade in die Fischerei des Moray Firth ist wesentlich jünger als die des Kabeljaunetzes; sie erfolgte erst im Herbst 1921. Dänische Motorboote hatten während des Kohlenstreiks gute Fänge an englische Häfen gebracht, und da wurde man auf dieses Gerät aufmerksam, das erst von englischen und danach auch von schottischen Fahrzeugen benutzt wurde. Die Umstände waren deshalb der Einführung der Wade besonders günstig, weil diese eine willkommene Ergänzung des Betriebes für kleinere Dampf- und Motorfahrzeuge ausserhalb der Heringsfangzeit bildete.

Die Anwendungsmöglichkeit dieses Gerätes ist an der schottischen Küste allerdings begrenzt, denn es kann nur dort benutzt werden, wo der Grund weich und frei von Unreinheiten ist. Der Moray Firth ist eins der am meisten mit der Wade befischten schottischen Gebiete, und zwar findet die stärkste Fischerei hier in der Zeit von Dezember bis März statt. Diese Gewässer werden aber auch in den Sommer- und Herbstmonaten wieder aufgesucht, besonders wenn Anzeichen für das Eindringen von Seehecht in dieses Gebiet vorhanden sind. Die Wiederfangorte von gezeichneten Schollen und Rotzungen, die zu der Hauptbeute dieser Fischerei gehören, geben ein gutes Bild von dem örtlichen Verlauf, der durch eine Karte veranschaulicht wird. Hieran knüpft der Verfasser ausserdem einige Bemerkungen über den Wiederfang der gezeichneten Fische und die Verbreitung der einzelnen Arten.

In den nächsten Abschnitten werden sehr ins Einzelne gehende Angaben über die Erträge der Wadenfischerei im Moray Firth gemacht, wobei immer zwischen den Anlandungen der Dampfer und Motorboote unterschieden wird. Zuerst werden die Fangmengen nach den verschiedenen

Fischereidistrikten besprochen, wobei besonders untersucht wird, welche Distrikte die grössten Anlandungen zeigen, wie sich die Anlandungen von Dampfern und Motorbooten auf die einzelnen Distrikte verteilen, und welche Veränderungen im Laufe der Jahre stattgefunden haben. Dann folgt eine Untersuchung der jahreszeitlichen Anlandungen, d. h. es wird die Zahl der Anlandungen, wieder getrennt nach Fahrzeugtypen, in drei Zeitabschnitten des Jahres errechnet. Auf das erste Drittel des Jahres fällt weitaus die grösste Zahl der Anlandungen, zwischen 48 bis 79 % je nach den Jahren und den einzelnen Fahrzeugtypen.

Von besonderem Interesse ist auch die Zahl der jährlichen Anlandungen und der Vergleich zwischen den einzelnen Jahren und bei den verschiedenen Fahrzeugen. Es ergibt sich, dass die Zahl der Dampferanlandungen fast ständig abgenommen, die der Motorbootsanlandungen ständig und sehr erheblich zugenommen hat. Natürlich ist die absolute Fangmenge der Motorboote geringer als die der Dampfer, aber die erwähnte Steigerung der Anlandungszahl kommt deutlich in der Steigerung des prozentualen Anteils, den die durch Motorboote gelandeten Gewichtsmengen an den Gesamtfangmengen haben, zum Ausdruck. Während 1922 die Motorboote nur 9 % der Gesamtfangmenge lieferten, waren es 1926 31 %.

Die mit der Wade gefangenen Fischarten sind recht mannigfach. An der Spitze steht im Durchschnitt der Jahre 1922—26 *Gadus aeglefinus* mit 23,8 % der Gesamtfangmenge, dann folgt *Pleuronectes platessa* mit 20,1 %, *Pl. microcephalus* mit 14,6 %, *Merluccius vulgaris* mit 13,3 %, *G. morrhua* mit 9,9 %, *Pl. cynoglossus* mit 7 %, und den Rest bilden verschiedene andere Fische. Trennt man aber die Fänge nach Fahrzeugen, so zeigt sich, dass der Anteil der einzelnen Fischarten am Gesamtfang bei Dampfern und Motorfahrzeugen ganz verschieden ist. Das wird dadurch verursacht, dass die verschiedenen Fahrzeugarten teilweise ganz verschiedene Fanggründe aufsuchen.

Eine Zusammenstellung über den Anteil der einzelnen Fischsorten an den Fängen nach Jahreszeiten zeigt die zeitliche Verschiedenheit der Zusammensetzung der Fänge. Es wird aber besonders darauf hingewiesen, dass es nicht die Gewichtsmenge ist, die bestimmend für die Auswahl der Fangplätze und damit für die Zusammensetzung der Fänge ist, sondern der Wert der Fänge.

Wie bei der ganzen vorliegenden Bearbeitung, unterwirft der Verfasser besonders bei der Frage nach den jährlichen Schwankungen das Material einer scharfen kritischen Prüfung. So wird darauf hingewiesen, dass Schwankungen in den Fängen abhängig von der Wahl der verschiedenen Fischgründe sind und nicht von natürlichen Schwankungen in der Häufigkeit der Fische. Es werden aber auch die Schwierigkeiten gezeigt, die bestehen, um ein möglichst einwandfreies Zeitmass zur Berechnung der Schwankungen zu finden.

Von besonderer Bedeutung ist schliesslich noch die Erörterung der Frage nach dem Einfluss, den die Einführung der Wade in die Fischerei des Moray Firth auf den dortigen Fischbestand ausgeübt hat. Zu Beginn der Erörterung dieser Frage wird ein kurzer Überblick über die Entwicklung und den Umfang der Wadenfischerei in jenen Gewässern gegeben. Daraus geht eine gewisse Abhängigkeit der Wadenfischerei von der Treib-

netzfischerei auf Heringe hervor, insofern als von dieser manche Fahrzeuge zu jener übergehen und umgekehrt, je nachdem ob die Aussichten in der Heringsfischerei ungünstig oder günstig erscheinen. Der Verfasser macht dann zwar den Versuch, durch verschiedene Berechnungen über die oben genannte Frage Aufschluss zu erhalten, aber abschliessend kommt er doch zu der Feststellung, dass die Unterlagen nicht ausreichend sind, um zu einem sicheren Urteil zu gelangen. Besonders fehlt es daran, dass weder die Fischstunden noch die genauen Fangplätze aus den statistischen Unterlagen erkennbar sind. SCHNAKENBECK.

HAROLD THOMPSON. The Haddock of the North-Western North Sea. (Haddock Biology. IV) Fishery Board for Scotland, Scientific Investigations 1927, No. III (January 1928)).

This paper forms a short review of the results obtained by the Scottish investigations on the haddock from the following three viewpoints:—

(1) Different growth types are recognized in Scottish waters, where the haddock everywhere grows slower than in the S.E. North Sea. In the latter area a 6 year haddock attains a length of 50 cm (growth type E) while haddock of the same age from shallow water near the Scottish coast only reach about 40 cm. (type W) and those from deeper water farther east even only about 33 cm. (type g).

(2) The general trend of migration has been studied, both by investigating fish caught in the different squares during all seasons, and by marking. The latter seems, however, not to have been particularly successful, the recaptures amounting to only 5 and 2 per. cent. in the two experiments executed.

It appears from the various data, especially the extensive fishery statistics, together with data as to amount of haddock roe found in fish stomachs that the entire haddock population of the N.W. North Sea shows a slight yearly oscillation, generally towards S.E. in summer, towards N.W. in winter. The greater part of the haddock grounds is, however, permanently more or less densely stocked.

(3) The fluctuations in the renewal of the stock of haddock are discussed, and special attention is given to the 1923-brood, the members of which not only were very numerous in E. Scottish waters but were also of a very large size. The preponderance of this year-class was very marked in all areas, even in the western Baltic in 1926, except in the Shetland area, where the 1920 brood was more numerous.

The results of Dr. THOMPSON's various investigations on the productivity of the various year broods are given in a most striking figure on p. 18, demonstrating quite extraordinary fluctuations, the poorest years (f.i. 1908, 1910, 1912, 1914, 1922) contributing not more than about one tenth of the numbers attributable to good broods as f.i. those from 1904, 1909, 1913, 1920, 1923. O. S.

JAS. JOHNSTONE and WINNIFRED E. FROST. Anelasma Squalicola (Lovén); its General Morphology. Report for 1926 of the Lancashire Sea-Fisheries Laboratory. Liverpool, pp. 29—91. 1927.

If life, to use SAMUEL BUTLER's epigrammatic definition, be nothing but the drawing of sufficient conclusions from insufficient data, then

Science, we feel, should either transpose the prefix from the first epithet to the second or else add it to the first. Not that in particular instances this always holds true, but like Nature, Science seems very careful of the type, and is as fond of uniformity as her twin sister of ecclesiastical persuasion, Authority.

The above observations were called forth, not by this interesting and excellent paper as a whole but by the efforts on the part of the authors as set out on page 83 to add a little Mendelian verisimilitude to otherwise bald facts. It is true that they write "in our modern jargon", and for that they deserve thanks, but the attempt to drag in a fashionable frilling to a dress the lines of which need, so to speak, no such superfluity, seems to us a work of ingenious supererogation, particularly when we consider that the theory in question is no longer at its zenith.

This being said by way of preface, we can touch in more detail on one or two important questions raised by this admirable paper. We note, with surprised pleasure, that Charles Darwin is referred to with respect, for we have often suspected that even if the idol have feet of clay, the clay extends still further in the anatomy of the professional iconoclasts.

After giving a brief but exhaustive bibliography of *Anelasma*, the authors proceed to state where it occurs on the host, how it is implanted and how the root system maintains it in its place. The third division, which treats of the reaction of the tissues of the host to the presence of the roots, is profoundly important. "Fig. 19", they write, "shows the alterations in the tissues of the fish that are induced by the presence of the parasitic growths. The muscle fibres are fewer, and tend to become smaller. There is a very great multiplication of nuclei that are seen in fig. 21 as occupying the nodal points of the connective tissue interfibrillar meshwork and this tends towards a condition of fibrosis; etc." and again: "What we have here is something in the nature of an 'inflammatory' reaction to a nocuous stimulus". They then describe typical inflammation as it occurs in a warm blooded animal, and continue: "Evidently this is not the condition that we see in the case of the fish infected by *Anelasma*, for here the irritation, and so the resulting 'inflammation' are 'chronic' conditions which appear to continue throughout a large part of the life of the host".

It might be expected that such a violent irritation as the inhesion of *Anelasma* in the flesh of the *Etmopterus* would set up a malignant connective tissue tumour, but this does not happen. "The host," the authors say, "appears to tolerate the parasite in a remarkable way," suggestive of the views held by the late J. Loeb on the influence of the organism as a whole on what must have become in some way an incorporated part. Apparently there is no castration of the host as has been observed in the case of certain crabs infected by species of *Sacculina*. On the other hand no systematic study has been made of the reproductive organs and general sexual characters of infected *Etmopteri*.

In division 12 the authors discuss the general histology of *Anelasma* and refer once more to the development of a *sacculina*, and they raise a question of great interest. "Suppose the cells," they write, "of *Sacculina interna* began to multiply without differentiation, we should have a 'cancerous' growth ..... Now, the *sacculina interna* is essentially different

from a malignant tumour in that it possesses the developmental factors of its species. A cancerous tumour has lost these developmental factors. Why?" They then proceed to describe the curiously simple histology of *Anelasma*, having previously suggested a de-differentiation and a re-differentiation of tissues to account for this curious point rather than suppose a lag in the differentiation of the embryonic tissues. Here, then, is another difficulty that calls for discussion and further elucidation. We hope that we have mentioned a sufficient number of interesting questions which suggest themselves on reading this paper to any one who is interested in the problem of growth.

At least we can congratulate the authors on having stated the problem and on having refrained, save for the example mentioned, from affixing old labels to new wine bottles in the fear that a new vintage may be a dangerous thing. There are seven plates containing forty one figures which for the most part are clear and satisfactory, although we could wish that the photograph plate 11 fig. 4 had been considerably larger. G. W. H.

Frances N. Clark. The Weight-Length Relationship of the Californian Sardine (*Sardina coerulea*) at San Pedro. California State Fisheries Laboratory. Fish Bulletin No. 12. Sacramento, 1928.

Carroll B. Andrews. Seasonal Average Length Trends at Monterey of the Californian Sardine (*Sardina coerulea*). California State Fisheries Laboratory. Fish Bulletin No. 13. Sacramento. 1928.

The first paper is a study of the variations of a factor, which, the author states, reflects the fat content of the fish, and is a reliable index of condition, based upon the formula $\frac{1000W}{L^3}$, where W is weight in gm. and L the length in mm. The factor so obtained can be compared with similar factors for the same length, but owing to the bad fit of the theoretical curve to the observed lengths and weights, especially at either end of the distribution, comparison between different lengths is not permissible.

The author finds that, for the same length, the factor varied from month to month and from season to season. Also whilst fish of 200 mm. and over gave diminishing factors from December to May, those of the smaller fish decreased from December to January or February, and increased thence to May. No data were collected for the remainder of the year. Fluctuations within a year-group could not be definitely determined, but indications pointed to the larger fish having a smaller factor than the lesser ones of the same age.

An attempt was made, by means of logarithmic manipulation, to determine a closer relationship between W and L, and the formula $\log W = 3{\cdot}15 \log L + \bar{6}{\cdot}73$ was evolved, but the author preferred to use the cubic form. The curious choice of frequencies actually shown in Fig. 11 leads to a wrong impression of the goodness of fit of the logarithmic equation, and it would seem, from a replotting of the frequencies, that the equation based upon $L\,3{\cdot}15$ fits the curve of distribution much better than the one based upon L^3, and unlike the latter, its factors are directly com-

parable for all different lengths up to about 260 mm. The value of the paper would therefore have been enchanced had this formula been used.

It is rather disconcerting to find that a logarithm quoted as $-6\cdot73$ should have read $\bar{6}\cdot73$ and also to find Fig. III printed upside down.

A very useful feature of the paper is a bibliography which gives, in a handy form, a full list of references to work which has previously been done on the relation between length and weight in fish.

The second paper traces the variation in the average length during the season June to March. The length was small and somewhat variable during the summer months, followed by an increase of several mm. in length and a decrease of the variation during the autumn. A gradual increase in both size and variation set in late in November, through December, to a maximum size at end of January or early February, followed by a slight decrease to the end of the season.

The author eliminates various other possible causes of the fluctuations, and suggests that they are possibly due to migratory movements of different schools of fish.

The method of smoothing the daily or twice weekly observations is by means of a moving average of 29 days. The curve so produced is meaningless so far as its short period fluctuations are concerned, and the plain fortnightly means would have yielded as good results in a clearer form with a greatly decreased expenditure of labour. It is also an unnecessary refinement to try to measure fish of 20 cm. in length to the nearest mm.

T. E.

Arvid R. Molander. Animal Communities on Soft Bottom Areas in the Gullmar Fjord. Kristinebergs Zoologiska Station 1877—1927, Nr. 2, Stockholm, 1928.

Following the suggestion of the Swedish Hydrographic-Biological Commission that researches concerning Petersen's animal communities should be conducted near home along the western coast, Dr. Molander proposed that two Bohuslän fjords of different character should be studied. His view was that, in all probability, these localities would offer facilities for a close study of the organisation of the various communities as to the degree to which they are dependent upon hydrographical conditions and minor variations in the nature of the bottom deposits. Gullmar and Stig were the fjords selected, the former being deep and the latter very shallow. Investigations began in June, 1923, and were repeated yearly during different months up to and including the year 1926. The paper now under review deals with the material collected from the Gullmar fjord and forms part of the jubilee publication issued in connection with the commemoration of the 50th anniversary of the foundation of the Kristineberg Zoological Station.

Dr. Molander uses the term "community" as synonymous with "association" to denote "a regularly recurring combination of certain type animals, as a rule also strongly represented numerically", and he retains the term "facies" for a distinct localised modification or variant

of a community. He selects his type animals mainly in accordance with the principles of PETERSEN, although, under the local circumstances, he finds it convenient to make considerable use of Polychaeta which abound in some districts.

As to the cause of the formation of the different communities, the author holds that while the character of the sea bottom may be of importance, it is in the first place the hydrographical factors that give rise to the communities. Thus he says:— ". . . . . The investigations of the fauna of the Gullmar fjord, its vertical distribution and its relation to salinity and temperature at the sea floor, readily reveal how, in accordance with diminishing salinity and changing temperature, the different communities replace each other from the deep levels of the fjord to the Zostera meadows, and that these changes occur, generally speaking, on the same kind of sea bottom. Within the limits of similar hydrographical conditions, on the other hand, the animal communities are no doubt affected by divergent conditions of the bottom. . . . ."

With regard to the distribution of certain communities, Dr. MOLANDER draws attention to the fact that certain species or groups of animals often entirely dominate a community and thereby check the development within the community of other animals that otherwise, from a hydrographical point of view as well as with regard to the nature of the bottom, would be able to thrive and spread there.

The characters and distribution of a total of nine communities in the Gullmar fjord and of the different facies are described, chief attention being paid to the seven communities found in clay bottoms. A synopsis is given in which the communities are classified according to the nature of the bottom, the depth, salinity and temperature at which they occur. It is shown that on clay bottom and at great depths there exist communities and facies which are confined to sea floor water of, as a rule, high salinity (34 to 35 per mille) and exclusively low temperature (about 4° to 7°). A second group of communities occurs within considerably wider hydrographical limits (salinity 34 to 20 per mille) and at depths varying from 70 m. up to the Zostera belt. Both temperature and salinity may vary markedly with the changing seasons of the year. Within this second group a sequence of communities is met with as the salinity decreases towards the shallower areas, the distribution of each community being dependent upon a certain range of variation in salinity. The distribution of the facies belonging to these communities, in most cases bears some relation to minor changes in the nature of the bottom deposits; clayey mud (ooze), hard clay, and more or less sand-mixed clay constitute three types of bottom deposits that are usually accompanied by such modifications of community formation. Facies may, however, be caused by minor variations in salinity.

In the detailed descriptions of the communities and facies, the ways in which the different associations agree with or differ from communities described from other waters are discussed. Very full tables of samples and species are appended which materially add to the value of the publication to outside workers.

E. F.

H. Hertling. Untersuchungen über die Ernährung von Meeresfischen. I. Quantitative Nahrungsuntersuchungen an Pleuronectiden und einigen anderen Fischen der Ostsee. Berichte der Deutschen Wissenschaftlichen Kommission für Meeresforschung. Neue Folge. Band IV, Heft 2, Berlin 1928. 124 pages, 11 figures, 4 plates, 1 chart and 11 tables in the appendix.

In connection with Professor Hagmeier's investigations of the bottom fauna in the Baltic there was collected from the research vessel "Poseidon" in April 1925 and July 1926 some material consisting of stomach and intestines of various food fishes, chiefly pleuronectids. This material was preserved in formaline and forms the basis for the work under review.

As the author rightly points out in his introduction, it would have been of great value in this case, where the main point is the comparison with results obtained from bottom-sampler investigations, if it had been possible to determine both the number and the weight (rough weight) of food animals in the fish; the author has, however, been compelled to confine himself to giving the number only of the various food animals which were found in the digestive organs of the fish, since the material was ill adapted to give a reliable basis for weight calculations. We see from this how important it is to carry out investigations on fresh material. Even if some of the stomach and gut contents is of course in a more or less digested state, it will always be possible when fresh material is utilized to determine the interrelationship existing between the quantities of the most important food animals; and when the dry weight of the soft parts has once for all been calculated for each species of animal separately we can always later convert the rough weight into dry weight. It is true that we still lack, as the author rightly remarks on page 9, determinations of the food values of the soft parts; but if we once have determined the rough weight such calculations also can be made later from this.

When therefore we have the choice between determining the number or the weight of food animals, there can be no doubt that we should choose to determine the weight; the difference in weight between the different species of animals, in fact also between large and small specimens of one and the same species, is so considerable that the number alone often gives a completely wrong idea of the importance of the species in question as food for the fish under investigation. If, however, we are quite aware of this — as is the author of the paper under review — the number of food animals can also afford us useful information. We must therefore be grateful for this work which on a purely quantitative basis institutes a comparison between the number of bottom animals consumed by the fish and the available number of bottom animals per square unit of sea bottom.

The author arrives at the conclusion that the molluscs and small crustaceans are in numbers the most important food animals for the pleuronectids in the Baltic. If we consider the entire material, consisting of 340 plaice, 338 flounders and 268 dab, we can say that the plaice is predominantly a consumer of molluscs, while flounders consume crustaceans in addition, and dabs consume more crustaceans than molluscs. Moreover the tables show, as was to be expected, that the fish under examination

contain on an average more food animals in July than in April, and that as their size increases they eat more lamellibranchs and fewer crustaceans; a few exceptions that have been found from this rule are doubtless due to the paucity of material.

In the *Tellina baltica* community, it is first and foremost the predominant species *T. baltica*, that the plaice consume; the smaller plaice also consume a large quantity of *Hydrobia*, as also many small *Cardium edule*, *Mytilus*, and *Mya arenaria* in summer. The larger the plaice become the more they tend to eat the larger *Mytilus*. Of the worms most in demand as food in this connection, the most important are *Nephthys* (the species is not mentioned but doubtless *N. ciliata* is meant), *Nereis diversicolor*, *Terebellides stroemii* and *Halicryptus spinulosus*, and of the crustaceans *Chiridothea entomon* is especially important; the small amphipods *Bathyporeia pilosa* and *Pontoporeia affinis* are found in large numbers in the smaller plaice, but as their weight is so small their importance is doubtless not very great. A number of fish, particularly *Ammodytes* serve as occasional food for the larger plaice. Whereas the plaice especially consume the lamellibranchs which are living in the bottom, it seems that the dabs most of all take the lamellibranchs living on the bottom as for instance *Mytilus*. As they increase in size the dabs tend more and more to eat lamellibranchs, but for the small and medium sized dabs the crustaceans are greatly in demand. Also fish such as *Gobius* and *Ammodytes* are of importance as food for the larger dabs. As regards the food of flounders, it is *Mytilus*, *Tellina baltica*, and *Cardium* that are chiefly consumed in the *Tellina baltica* community, also some few worms and many crustaceans, but very few fish.

In the *Syndosmya alba — Tellina calcarea* community the pleuronectids eat many lamellibranchs, especially the two mentioned characteristic animals, but the plaice also eat young *Cyprina* amongst others. Of worms, many *Nephthys*, *Scoloplos armiger*, *Halicryptus* and *Priapulus* especially serve as food. Amongst the small crustaceans, amphipods are not now the most important, but rather the *Cumacea*, in particular *Diastylis rathkei* and *Leptostylis ampullacea*.

In the "mixed animal community", the intermediate area between the *baltica* and *calcarea* communities, the pleuronectids eat, as was to be expected, both *Tellina baltica* and *T. calcarea*, mainly, however, the latter. Of crustaceans, *Diastylis rathkei* is especially consumed.

In the "poor" animal community in Gotland Deep, where molluscs are lacking, the dabs and flounders feed predominantly on worms, particularly *Harmothoë sarsi;* second in importance are the crustaceans such as *Chiridothea entomon* and *Pontoporeia femorata*. With the aid of numerous and very complete tables the author thereupon shows that the results of Professor Hagmeier's valuation investigations agree closely with those obtained from the examination of stomach contents, since those species of bottom animals which the bottom-sampler investigations have proved to be characteristic for a definite part of the sea are also found in larger or smaller numbers in the stomachs of the pleuronectids living there. But it seems to be only some few species, yet occurring very frequently, which constitute the bulk of the pleuronectid's food in the Baltic,

viz. *Tellina baltica* and *T. calcarea* of a certain size, young *Cardium* and *Mya*, certain crustaceans such as the *Pontoporeia* and *Bathyporeia* species, *Corophium* and *Diastylis*. Other species which are also very common, such as the polychaets *Terebellides stroemii* and *Scoloplos armiger*, are much less frequently eaten by flatfish if the latter have easy access to lamellibranchs and crustaceans. The bottom content of food animals can moreover at nearly all the places investigated be characterized as good, often as very good, and the fish contained abundant quantities of food.

Of turbot and cod a lesser number have been examined; the former live mainly on fish, the large ones especially on *Ammodytes*, the smaller on *Gobius*, also on crustaceans such as mysids and *Crangon*. The smaller cod consume mostly mysids and other crustaceans and small fish, while the larger (over 40 cm.) eat to an increasing degree fish, especially *Ammodytes* and *Lumpenus*, but also crustaceans such as *Chiridothea entomon*. In 24 *Cottus scorpius* the author found fish (*Ammodytes*, *Gobius*) and crustaceans (mysids, *Crangon*, amphipods and — especially — *Chiridothea entomon*).

The material under discussion is as a whole well and clearly arranged, and the illustrations (with the exception of Fig. 4, Table 2) are good. In the opinion of the present reviewer, however, there are too many tables, a large number of them being based on a too scanty material, often only a few fish. But it must be granted that the author has accomplished the great work of counting the food animals in a consistent manner and with constant reference to the quantitative bottom investigations which were proceeding simultaneously. It is therefore with great satisfaction that we learn from the title of the book and the remarks of the author in the introduction that this work is published as the first of a series of comprehensive investigations on the food of marine fishes.

H. Blegvad.

A. C. Stephen. Notes on the Biology of *Tellina tenuis* da Costa. Journal of the Marine Biological Association, New Series. Vol. XV, No. 2. pp. 683—702. Plymouth 1928.

The biology of even the most common marine bottom animals is even in these days for the greater part unknown, or in any case very little known. We must therefore be grateful for the publication of any work, such as the one which lies before us, dealing with the subject. The author by measuring a large number of *Tellina tenuis*, taken the whole year round from various depths in Kames Bay on the Cumbrae in the Firth of Clyde, and by supplementing them with occasional samples from various other bays in the Cumbrae has sought to discover the growth and age-groups of this lamellibranch. He comes to the conclusion that in Kames Bay in 1927 there were four age classes, of which one year class (1925) was very poorly represented; in 1927 no considerable spat fall occurred, whereas on the other hand the year classes 1924 and 1926 were abundantly represented, so that "since 1924 there have been alternate good and bad years of spat fall".

The author arrives at this conclusion solely from considering the size-frequency curves of individuals taken at various seasons of the year; as

is rightly observed on page 698, confirmatory work is necessary to settle in how far the annual increment varies from season to season. It seems to the present reviewer that such a confirmation of the interpretation of the measurement curves should be sought by making aquarium experiments in connection with a study of the growth rings similar to Ford's investigations of the growth rings of *Syndosmya alba*, *Cardium echinatum*, and *Spisula solida*.

A noteworthy fact is the great difference in number and size between the individuals from the low-water mark and those from stations above this level. Whilst the number decreases uniformly the nearer we approach the high-water mark the size of the individuals increases. This is due according to the author to their more rapid growth here. Below the low-water mark the size of the individuals further decreases but the results from these stations are not comparable with the numbers for the stations above the low-water mark, since the collections at the latter stations were made by digging up $^1/_4$ sq. metre of the sand to a depth of 15 cm., whereas at the other stations a Robertson bucket dredge was used which collected 20 ccm. of sand or mud; it is not surprising that such a dredge with its skimming action (mentioned on page 684) mainly picks up the smaller individuals.

We get some idea of what enormous numbers of *Tellina tenuis* there must be in Kames Bay when we learn that 1897 individuals were dug up in $^1/_4$ sq. metre of sand.

The spatting season is stated to be in the summer and autumn months; in August most of the young brood was found below low-water mark, in October the spat was also found deposited in large numbers up to the half-tide mark and in lesser numbers in the higher levels.

In the winter months the food consisted solely of detritus, and, during the spring diatom increase, of diatoms, but already in the early summer detritus again constituted part of the food.

It is of interest to note that *Tellina fabula*, which is also abundant in Kames Bay, seems in its distribution to be complementary to *T. tenuis*, the latter disappearing at depths of 4—6 fathoms and being replaced by *T. fabula*, which again disappears at a depth of 11 fathoms.

As the author himself remarks, the above-mentioned results can only be regarded as of a preliminary nature since "this work was begun as part of a much larger scheme of investigation on the Clyde fauna, especially in regard to the age and renewal of certain groups of bottom-dwelling organisms, and to the numbers and season of appearance of the young broods". We can therefore look forward to several more papers on this interesting subject.

H. Blegvad.

C. M. Yonge. The Absorption of Glucose by *Ostrea edulis*. Journal of the Marine Biological Association, New Series. Vol. XV, No. 2. pp. 643—653. Plymouth 1928.

A whole series of papers have appeared dealing with the greening of oysters. Most recently of all G. Ranson in four papers from 1924 to 1927 has sought to show that the greening is caused by the oily green pigment

(Marennin) from the diatom *Navicula ostrearia* dissolving in the water in which the oysters live and being absorbed directly therefrom by the epithelia of the gills, palps, and mantle cavities of these animals.

Yonge in the little paper under review has shown by a series of experiments that when normal oysters with openings drilled in both the inhalant and exhalant chambers were placed in sea-water containing about 0.2 per cent. of glucose, the glucose content was diminished on an average by 8.17 per cent. at the end of 36 hours. But if the same oysters were plugged by covering the mouth and palps with wax and plasticine the average diminution of the glucose content was only 1.46 per cent. after 36 hours. In two of the experiments there was no diminution at all, and in the three others there was evidence that one of the two oysters in each had been incompletely plugged, since glucose was found in their stomachs. Moreover if in the third series of experiments oysters which had been plugged for 8 days so that they were "bleeding" profusely, i.e. contained large quantities of leucocytes in the mantle cavities, were placed in the same solution of glucose the average diminution of the glucose content was 7.4 per cent.

The author concludes from these and previous experiments that the free ciliated epithelia of oysters and other lamellibranchs cannot absorb directly. Absorption takes place in the tubules of the digestive diverticula (the "liver"), and, in the mantle cavity, only through the agency of the phagocytes which are extruded in great numbers when lamellibranchs "bleed" as a result of bad conditions. Ranson's theory cannot therefore in the opinion of the author be upheld; in greened oysters the marennin must have entered the cells through the agency of the phagocytes which either absorb it directly from the mantle cavity and gut or transport it from the digestive diverticula. He is of the opinion that it is not impossible that marennin is absorbed in the first-mentioned manner in the "claires" at Marennes "where the temperature and salinity of the water both become exceptionally high in the periods between spring-tides, thus possibly causing extensive 'bleeding' in the oysters".

This latter theory should, however, in the opinion of the present reviewer be more closely investigated by direct observations. H. Blegvad.

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Prepared by the Editor with the assistance of Miss THURSBY-PELHAM.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in the North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

The classification of entries follows in a general way that adopted in Dr. ALLEN's Selected Bibliography published in Vol. I, Nos. 1 and 2 of the Journal, and since reprinted.

Subscribers and those on the distribution list will receive regularly upon application to the Administrative Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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